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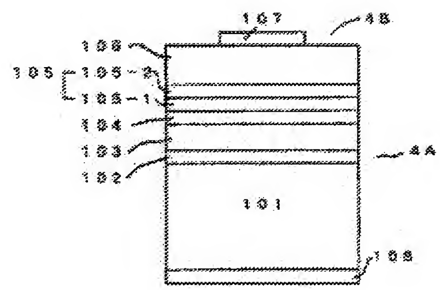
(54) PN-JUNCTION TYPE COMPOUND SEMICONDUCTOR LIGHT EMITTING DEVICE, METHOD FOR MANUFACTURING THE SAME, AND WHITE LIGHT EMITTING DIODE

(57)Abstract:

PROBLEM TO BE SOLVED: To provide in a simplified way a pn junction type compound semiconductor light emitting device presenting multi-wavelength luminescence.

SOLUTION: In a light emitting device having a first barrier layer made of an undoped first conduction type boron phosphide semiconductor formed on a substrate and a light emitting layer, formed on the first barrier layer and constituted of a plurality of layers of group III nitride semiconductors different in band gaps and overlapping each other, the light emitting layer constituting layer nearest to the first barrier layer is made of a group III nitride semiconductor including phosphorus P.



CLAIMS

[Claim(s)]
[Claim 1]A substrate which consists of crystals, and the 1st barrier layer that were provided on a substrate and that is undoped and consists of a Lynn-ized boron system semiconductor of the 1st conduction type, . Make it come to stratify two or more composition layers which were provided on the 1st barrier layer and which consist of a group III nitride semiconductor which is mutually different in a band gap. In a pn junction type compound semiconductor light emitting element provided with a luminous layer of the 1st or 2nd conduction type, A pn junction type compound semiconductor light emitting element, wherein a composition layer (1st luminous layer composition layer) of a luminous layer provided in a side nearest to the 1st barrier layer comprises a group III nitride semiconductor containing Lynn (P).
[Claim 2]The pn junction type compound semiconductor light emitting element according to claim 1, wherein a substrate is a silicon (Si) monocrystal substrate.
[Claim 3]A composition layer of a luminous layer, Claim 1 consisting of phosphorus nitride-ized gallium indium ($Ga_XIn_{1-X}P_{1-Y}N_Y$:0 <=X <=1, 0< Y<1) or phosphorus nitride-ized gallium ($GaP_{1-Y}N_Y$:0<Y<1). Or a pn junction type compound semiconductor light emitting element given in 2.
[Claim 4]A pn junction type compound semiconductor light emitting element given in any 1 paragraph of Claims 1-3 to which the 1st barrier layer is characterized by making large an at least 0.1-eV or more band gap rather than any of two or more luminous layer composition layers which constitute a luminous layer.
[Claim 5]A pn junction type compound semiconductor light emitting element given in any 1 paragraph of Claims 1-4, wherein an interlayer who consists of group III nitride semiconductors is formed on the surface of the 1st barrier layer, it joins this interlayer and the 1st luminous layer composition layer is provided.
[Claim 6]The pn junction type compound semiconductor light emitting element according to claim 5 comprising a group III nitride semiconductor with which an interlayer has a band gap more than a group III nitride semiconductor which constitutes the 1st luminous layer composition layer.
[Claim 7]The pn junction type compound semiconductor light emitting element according to claim 5 or 6 comprising a group III nitride semiconductor containing an element which constitutes a group III nitride semiconductor with which an interlayer makes the 1st luminous layer composition layer.
[Claim 8]A pn junction type compound semiconductor light emitting element given in any 1 paragraph of Claims 1-7, wherein the 2nd barrier layer that is undoped and consists of a Lynn-ized boron system semiconductor of the 2nd conduction type is provided in the surface of a luminous layer composition layer which makes the outermost layer of a luminous layer.
[Claim 9]The pn junction type compound semiconductor light emitting element according to claim 8, wherein a luminous layer composition layer which makes the outermost layer of a luminous layer comprises a group III nitride semiconductor of the 1st or 2nd conduction type containing Lynn (P).
[Claim 10]On a substrate which consists of crystals, it is undoped and the 1st barrier layer that consists of a Lynn-ized boron system semiconductor of the 1st conduction type is formed, further -- this -- it makes it come to stratify two or more composition layers which consist of a group III nitride semiconductor which is mutually different in a band gap on the 1st barrier layer. In a manufacturing method of a pn junction type compound semiconductor light emitting element which forms a luminous layer of the 1st or 2nd conduction type, A manufacturing method of a pn junction type compound semiconductor light emitting element constituting a composition layer (1st luminous layer composition layer) of a luminous layer provided in a side nearest to the 1st barrier layer from a group III nitride semiconductor containing Lynn (P).
[Claim 11]A manufacturing method of the pn junction type compound semiconductor light emitting element according to claim 10 forming an interlayer who consists of group III nitride semiconductors on the surface of the 1st barrier layer, joining this interlayer and forming the 1st luminous layer composition layer.
[Claim 12]A manufacturing method of the pn junction type compound semiconductor light emitting element according to claim 10 or 11 forming the 2nd barrier layer that is undoped and consists of a Lynn-ized boron system semiconductor of the 2nd conduction type in the surface of a luminous layer composition layer which makes the outermost layer of a luminous layer.
[Claim 13]A white light emitting diode which becomes any 1 paragraph of Claims 1-9 from a pn junction type compound semiconductor light emitting element of a description.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[Field of the Invention]This invention relates to the art for constituting the luminous layer which makes it come to stratify two or more composition layers which start a pn junction type compound semiconductor light emitting element, especially bring about luminescence of a multi-wavelength in the pn junction type compound semiconductor light emitting element of multicolor luminescence.
[0002]
[Description of the Prior Art]Conventionally, III fellows nitriding **** semiconductors, such as gallium nitride indium ($Ga_XIn_{1-X}N$:0 <=X <=1), are used as a component of the luminous layer for emitting short wavelength light, such as blue, in a light emitting diode (LED) (refer to JP,S55-3834,B). In $Ga_XIn_{1-X}N$ (0<=X<=1), it is found gallium (Ga) composition ratio (=X) and that a band gap (bandgap) similarly changes steeply nonlinearly corresponding to an indium composition ratio (=1-X) (refer to above-mentioned JP,S55-3834,B). For example, in $Ga_XIn_{1-X}N$ of a hexagonal wurtzite (Wurtzite) crystal form. The band gap in a room temperature is reduced to about 2.9 eV by setting indium composition to 0.2 from about 3.4 electron volts (unit: eV) of gallium nitride (GaN) (refer to above-mentioned JP,S55-3834,B). Thus, if it is in $Ga_XIn_{1-X}N$ (0<=X<=1), it has the advantage which can give change to a luminous wavelength by making it change slightly [an indium composition ratio (=1-X)].
[0003]In the light emitting device of the conventional multicolor luminescence, the example which constitutes the luminous layer which brings about luminescence of the multi-wavelength which is different in a luminous wavelength from two or more gallium nitride indium ($Ga_XIn_{1-X}N$:0 <=X <=1) layers which are different in indium composition (=1-X) is indicated. For example, for an invention given in JP,2001-168384,A (June 22, Heisei 13 (2001) public presentation). The art which constitutes the luminous layer which brings about luminescence of a multi-wavelength from a three-layer $Ga_XIn_{1-X}N$ (0<=X<=1) well (well) layer which differs in an indium (In) presentation mutually is indicated. For example, LED which makes the two-layer $Ga_XIn_{1-X}N$ (0<=X<=1) layer which is different in indium composition stratify, and presents two waves of luminescence comprises an invention of JP,H11-289108,A (October 19, Heisei 11 (1999) public presentation). LED possessing the luminous layer which makes it come to stratify two or more $Ga_XIn_{1-X}N$ (0<=X<=1) layers which are different in indium composition of the multi-wavelength is indicated also to the invention of JP,H10-22525,A (January 23, Heisei 10 (1998) public presentation).
[0004]The multicolor light emitting device provided with the luminous layer which brings about luminescence of the multi-wavelength which is different in the conventional luminous wavelength has the composition of having a light-emitting part of pn junction type hetero (different species: hetero) joining structure. In order to achieve increase of the intensity of luminescence especially, the light-emitting part has double hetero (DoubleHetero:DH) structure (the Teramoto ****, "semiconductor device introduction" (refer to Baifukan Issue First edition and 124-125 pages on March 30, 1995).). The light-emitting part of DH joining structure comprises joining structure of a luminous layer, and n form or the barrier (clad) layer of p form which pinches it in the middle. The cladding layer which is in the conventional multicolor light emitting device, and pinches a $Ga_XIn_{1-X}N$ (0<=X<=1) luminous layer, Usually it comprises an n form or gallium aluminum nitride ($aluminum_XGa_{1-X}N$:0 <=X <=1) of p form (refer to above-mentioned ** JP,2001-168384,A, ** JP,H11-289108,A, and ** JP,H10-22525,A each gazette).
[0005]
[Problem(s) to be Solved by the Invention]however -- being based on the non-shrink band band (band) structure of a valence band peculiar to a wurtzite type crystal (Ikoma Toshiaki.) The Ikoma Hideaki collaboration, "a guide to basic physical properties of a compound semiconductor" (on September 10, 1991.) Gallium-aluminum-nitride indium ($aluminum_{alpha}Ga_{beta}\ In_{gamma}N$: 0<=alpha<=1, 0<=beta<=1, 0<=gamma<=1, alpha+beta+gamma=1) of Baifukan Issue First edition, referring to the 17 page, and the low resistance that presents the conduction type of p form cannot be formed easily. If it depends on usually [of conventional technology], in order to obtain p form group III nitride semiconductor layer of low resistance, the -- it is carried out [that it is necessary to heat-treat for desorbing a hydrogen atom (proton) from the inside of a same layer, and], after adding p type impurities, such as II group element, intentionally (doping) and forming a group III nitride semiconductor layer (refer to JP,H5-183189,A).
[0006]********, even if it is going to use the $aluminum_{alpha}Ga_{beta}In_{gamma}N$ (0<=alpha<=1, 0<=beta<=1, 0<=gamma<=1, alpha+beta+gamma=1) layer of the low resistance obtained via the complicated heat treatment process etc. as a barrier layer, Shortly, restrictions are produced in an order of making the $Ga_XIn_{1-X}N$ (0<=X<=1) layer which constitutes a

luminous layer laminating. For example, differ in a band gap mutually, namely, carry out the three-layer $Ga_XIn_{1-X}N$ layer which is different in a luminous wavelength, and it faces constituting the luminous layer of a multiwavelength emission use, There are restrictions which must arrange the smallest $Ga_XIn_{1-X}N$ layer of the band gap which brings about luminescence of long wavelength most in the middle of three layers (refer to above-mentioned JP,2001-168384,A). This in group III nitride semiconductors, such as $aluminum_{alpha}Ga_{beta}In_{gamma}N$ (0<=alpha<=1, 0<=beta<=1, 0<=gamma<=1, alpha+beta+gamma=1). It is for making the radiative recombination of the electron hole and electron which were poured in in order that the diffusion length (diffusion length; it corresponds to mobility) of an electron hole (hole) might take into consideration that a figure single [about] is also small as compared with an electron (electron) and might bring about luminescence cause on the average on each class.

[0007]Namely, the barrier layer which pinches the luminous layer which consists of layered structure of two or more $Ga_XIn_{1-X}N$ (0<=X<=1) layers which bring about luminescence of a multi-wavelength, The problem of the conventional technology constituted from $aluminum_{alpha}Ga_{beta}In_{gamma}N$ (0<=alpha<=1, 0<=beta<=1, 0<=gamma<=1, alpha+beta+gamma=1), (1) Since there is a big difference in diffusion length in (2) electron holes and an electron and it cannot obtain simply p form conduction layer of low resistance suitable for constituting a barrier layer, it is that restriction is added to the built-up sequence of the composition layer of a luminous layer. This invention was made in view of the problem of the above-mentioned conventional technology, and can constitute simply the low resistive layer of (A) p type and the conduction type of the both sides of n form, without requiring a complicated post process, Moreover, it supposes that a barrier layer is constituted from a compound semiconductor material which does not very have a big difference, it has in the (B) electron hole and the degree of electron transfer, and the compound semiconductor light emitting element possessing the light-emitting part of the pn junction type heterojunction structure which can be constituted simple is provided.

[0008]

[Means for Solving the Problem]Namely, a substrate with which this invention consists of (1) crystal and the 1st barrier layer that were provided on a substrate and that is undoped and consists of a Lynn-ized boron system semiconductor of the 1st conduction type, . Make it come to stratify two or more composition layers which were provided on the 1st barrier layer and which consist of a group III nitride semiconductor which is mutually different in a band gap. In a pn junction type compound semiconductor light emitting element provided with a luminous layer of the 1st or 2nd conduction type, A pn junction type compound semiconductor light emitting element, wherein a composition layer (1st luminous layer composition layer) of a luminous layer provided in a side nearest to the 1st barrier layer comprises a group III nitride semiconductor containing Lynn (P).

(2) A pn junction type compound semiconductor light emitting element given in the above (1), wherein a substrate is a silicon (Si) monocrystal substrate.

(3) A composition layer of a luminous layer, The above (1) consisting of phosphorus nitride-ized gallium indium ($Ga_XIn_{1-X}P_{1-Y}N_Y$:0 <=X <=1, 0< Y<1) or phosphorus nitride-ized gallium ($GaP_{1-Y}N_Y$:0<Y<1). Or a pn junction type compound semiconductor light emitting element given in (2).

(4) The above (1) whose 1st barrier layer is characterized by making large an at least 0.1-eV or more band gap rather than any of two or more luminous layer composition layers which constitute a luminous layer thru/or a pn junction type compound semiconductor light emitting element given in any 1 paragraph of (3).

(5) The above (1), wherein an interlayer who consists of group III nitride semiconductors is formed on the surface of the 1st barrier layer, it joins this interlayer and the 1st luminous layer composition layer is provided thru/or a pn junction type compound semiconductor light emitting element given in any 1 paragraph of (4).

(6) A pn junction type compound semiconductor light emitting element given in the above (5) comprising a group III nitride semiconductor with which an interlayer has a band gap more than a group III nitride semiconductor which constitutes the 1st luminous layer composition layer.

(7) The above (5) comprising a group III nitride semiconductor containing an element which constitutes a group III nitride semiconductor with which an interlayer makes the 1st luminous layer composition layer, or a pn junction type compound semiconductor light emitting element given in (6).

(8) The above (1), wherein the 2nd barrier layer that is undoped and consists of a Lynn-ized boron system semiconductor of the 2nd conduction type is provided in the surface of a luminous layer composition layer which makes the outermost layer of a luminous layer thru/or a pn junction type compound semiconductor light emitting element given in any 1 paragraph of (7).

(9) A pn junction type compound semiconductor light emitting element given in the above (8), wherein a luminous layer composition layer which makes the outermost layer of a luminous layer comprises a group III nitride semiconductor of the 1st or 2nd conduction type containing Lynn (P).

(10) On a substrate which consists of crystals, it is undoped and the 1st barrier layer that consists of a Lynn-ized boron system semiconductor of the 1st conduction type is formed, further — this — it makes it come to stratify two or more composition layers which consist of a group III nitride semiconductor which is mutually different in a band gap on the 1st barrier layer. In a manufacturing method of a pn junction type compound semiconductor light emitting element which forms a luminous layer of the 1st or 2nd conduction type, A manufacturing method of a pn junction type compound semiconductor light emitting element constituting a composition layer (1st luminous layer composition layer) of a luminous layer provided in a side nearest to the 1st barrier layer from a group III nitride semiconductor containing Lynn (P).

(11) A manufacturing method of a pn junction type compound semiconductor light emitting element given in the above (10) forming an interlayer who consists of group III nitride semiconductors on the surface of the 1st barrier layer, joining this interlayer and forming the 1st luminous layer composition layer.

(12) A manufacturing method of a pn junction type compound semiconductor light emitting element the above (10) forming the 2nd barrier layer that is undoped and consists of a Lynn-ized boron system semiconductor of the 2nd conduction type in the surface of a luminous layer composition layer which makes the outermost layer of a luminous layer, or given in (11).
(13) A white light emitting diode which becomes the above (1) thru/or any 1 paragraph of (9) from a pn junction type compound semiconductor light emitting element of a description. It comes out.
[0009]
[Embodiment of the Invention]In a 1st embodiment of this invention, various crystals can be used for a substrate as a substrate. the [for example, /, such as n form or silicon (Si) of the conductivity of p form, and silicon carbide (SiC),] -- IV fellows' semiconductor single crystal and the group-III-V-semiconducter single crystal of gallium phosphide (GaP) can be used as a substrate. although the crystal face of the surface of a substrate is unquestioned, if it is usually in {1.0.0.}, {1.1.0.} or {1.1.1.} crystal face, and a hexagonal crystal -- {0.0.0.1.} -- or -- {-- 1.1. -- usually considers it as a -2.1.} crystal face. The single crystal which uses an angle and uses abundance and the sloping crystal face as the surface from the crystal face of the above-mentioned mirror (Miller) index of the low next can also be used as a substrate. Although insulating alpha-alumina (alpha-aluminum$_2$O$_3$) single crystal and perovskite crystal form oxide single crystal can be used as a substrate, if a conductive single crystal is used as a substrate, Positive/negative and which polar ohmic (Ohmic) nature electrode can be constructed as a rear electrode at the rear face of a substrate, and it can contribute for constituting light emitting devices, such as LED, simple. It may be in using a conductive single crystal as a substrate, and n form or any of p form may be sufficient as the conduction type of a single crystal. The low conductive monocrystal substrate of specific resistance (resistivity), as for, below 1 milli ohm (momega) and cm carry out resistivity contributes for bringing about LED with low forward voltage (what is called V_f). It becomes effective in constituting LD which brings about the oscillation stable since it excelled in heat dissipation nature.
[0010]The 1st barrier layer provided on the above-mentioned crystal substrate constitutes boron (B) and Lynn (P) from a Lynn-ized boron system compound semiconductor layer included as a composing element by this invention. For example, it constitutes from $B_{alpha}aluminum_{beta}Ga_{gamma}In_{1-alpha-beta-gamma}P_{1-delta}As_{delta}$ (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0<alpha+beta+gamma<=1, 0<=delta<1). For example, it can constitute from $B_{alpha}aluminum_{beta}Ga_{gamma}In_{1-alpha-beta-gamma}P_{1-delta}N_{delta}$ (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0<alpha+beta+gamma<=1, 0<=delta<1). The 1st barrier layer is a barrier layer which approaches by the surface of a crystal substrate in [barrier layer / below-mentioned / 2nd] position, and is provided. By this invention, the 1st conduction type is tentatively called to the conduction type of the Lynn-ized boron system semiconductor layer which makes the 1st barrier layer. It is preferred for the conduction type of the crystal which is by using a conductive crystal as a substrate to constitute a light emitting device, and forms a substrate to consider it as the 1st conduction type. For example, on the Si single crystal substrate ({111}-Si single crystal substrate) which has p{1.1.1.} crystal face, the 1st barrier layer that consists of a Lynn-ized boron system semiconductor layer of p form is provided. [of type] If the buffer layer which is amorphous between the Lynn-ized boron system semiconductor layer of the 1st conduction type and crystal substrate which constitute the 1st barrier layer, or becomes from polycrystal is provided and the 1st barrier layer is provided via this buffer layer on a substrate, The 1st barrier layer that is excellent in crystallinity with few misfit (misfit) rearrangements etc. can be obtained. It is because the operation which therefore eases the lattice mismatch (mismatch) of the single crystal material of a substrate and the Lynn-ized boron system semiconductor layer of the 1st conduction type to the above-mentioned buffer layer is demonstrated.
[0011]the 1st barrier layer does not add the impurity for controlling conduction type intentionally (doping) -- it can constitute from a so-called Lynn-ized boron system semiconductor layer of undoped (undope) suitably especially. If the Lynn-ized boron (boron-monophosphide:BP) of a monomer typical as a Lynn-ized boron system semiconductor is made into an example and explained, to BP. The Lynn (P) atom which occupies a boron (B) hole (vacancy), or the boron (B) atom which occupies the Lynn (P) hole has already existed so much in the state of [undoped] the thing depending on a growing condition. Committing Lynn which occupies a boron hole as the donor (donor), the boron which occupies the Lynn hole acts as the acceptor (acceptor). and the donor or acceptor component in which these holes participate is undoped, and p form of low resistance or the conductive layer of n form is brought about -- it being alike and having sufficient concentration -- the inside of BP layer -- about -- it may exist so much exceeding 10^{19} cm^{-3}. Therefore, the necessity of constituting from a Lynn-ized boron system semiconductor layer which doped n form or p type impurities for daring to control conduction type for a barrier layer is lost. Namely, if the 1st barrier layer is constituted from a undoped phosphorus-ized boron system semiconductor layer, It is not necessary to carry out complicated conventional technologies, such as heat treatment for not requiring the complicated operation which dopes an impurity of a different kind depending on conduction type, and obtaining the p type layer of low resistance, and there is an advantage which can obtain the 1st barrier layer that has the conductivity of low resistance simply.
[0012]As for the 1st barrier layer, it is desirable to make a band gap large, and it is more desirable than any of two or more luminous layer composition layers which constitute a luminous layer to constitute from a Lynn-ized boron system semiconductor layer which makes large desirably a 0.2-eV or more band gap at least 0.1 eV or more. As compared with the greatest forbidden band of a luminous layer composition layer, the 1st barrier layer can consist of still more suitably Lynn-ized boron system semiconductor layers of a band gap big about 0.3 eV - 0.4 eV. Especially the Lynn-ized boron system semiconductor layer that sets a band gap to less than about 6 eV at not less than about 2.8 eV can be suitably used as the 1st barrier layer. For example, the band gap in a room temperature the 3.0 boron [Lynn-ized] (BP) layer of the monomer which shall be **0.2 eV, In the organometal chemistry gaseous phase depositing (MOCVD) method, it can form at not less than 750 ** the temperature of 1200 ** or less by making suitable the rate of the ratio of concentration

(what is called a V/III ratio) and growth rate of the source of a composing element which are supplied to a MOCVD growth reaction system. For example, it can form by setting a growth rate as 2 nm/m - 30 nm/m or less. The thickness of the Lynn-ized boron system semiconductor layer of the 1st conduction type which makes the 1st barrier layer exceeds about 50 nm, and it is preferred for it that it is about 3000 nm or less. It is suitable that carrier concentration is below abbreviation 1×10^{20} cm^{-3} above abbreviation 7×10^{17} cm^{-3}. Since the career exists in it at the high concentration about 10^{19} cm^{-3} - 10^{20} cm^{-3} even if undoped to the Lynn-ized boron system semiconductor, the conductive layer of the low resistance about several meter ohm-cm suitable for constituting a barrier layer is obtained simply.

[0013]On the 1st [of the 1st conduction type] barrier layer, the luminous layer which made two or more composition layers which are different in a band gap stratify is laminated. Each composition layer which makes a luminous layer can consist of group III nitride semiconductor layers, such as for example, gallium nitride indium ($Ga_XIn_{1-X}N$:0 <=X <=1) or phosphorus nitride-ized gallium ($GaP_{1-Y}N_Y$:0<Y<1). The band gap of $GaP_{1-Y}N_Y$ (0< Y<1), Corresponding to a slight change of a nitrogen presentation (=Y) or the Lynn presentation (=1-Y), it is nonlinearly changed rapidly like $Ga_XIn_{1-X}N$ (0<=X<=1) (refer to Appl.Phys.Lett., 60 (1992), and 2540-2542 pages). For this reason, $GaP_{1-Y}N_Y$ (0< Y<1) can be suitably used as a composition layer of the luminous layer for bringing about luminescence of long wavelength comparatively. The luminous layer can make the composition layer which consists of a different group III nitride semiconductor material able to stratify, and can also be constituted. For example, gallium nitride (GaN), a gallium nitride indium mix crystal ($Ga_XIn_{1-X}N$: in this case) The three-layer composition layer which consists of a mutually different group III nitride semiconductor material called 0<=X<1 and phosphorus nitride-ized gallium ($GaP_{1-Y}N_Y$:0<Y<1) is made to stratify, and a luminous layer can be constituted. As for a composition layer, although there is no limitation in the quantity of the composition layer for constituting a luminous layer particularly, it is usually desirable from generally luminescence of a desired color tone being depended and concluded as the mixed colors of three colors to consider it as about at most three layers. It is necessary to unify the conduction type of each composition layer into the 1st or 2nd conduction type. If the luminous layer of the 2nd conduction type that becomes the 1st barrier layer of the 1st conduction type from the composition layer of the 2nd conduction type is joined, the light-emitting part of pn junction type single hetero (SingleHetero:SH) can be constituted.

[0014]Even if the carrier concentration of each composition layer which constitutes a luminous layer is different, there is no inconvenience. Even if the thickness of each composition layer which constitutes a luminous layer is different, there is no inconvenience, but if the thickness of a luminous layer composition layer which usually brings about luminescence of wavelength with low spectral luminous efficacy considers it as size as compared with other layers, when carrying out mixed colors, suitable color rendering properties will be acquired. For example, the mixed colors of the luminescence of the blue which has a relation of the complementary color, and yellow are carried out, it is in making white light profitably like, and the example which makes thicker than that of the luminous layer composition layer which emits yellow light thickness of the luminous layer composition layer which emits the blue glow whose spectral luminous efficacy is lower than yellow light can be given. In LED of the method which takes out luminescence to the outer direction of an opposite hand with a monocrystal substrate, it is desirable to approach the monocrystal substrate side most and to arrange the luminous layer composition layer which brings about luminescence of long wavelength most. For example, it is in obtaining the luminous layer which emits white light from the composition layer which emits light in each of the above-mentioned blue glow and yellow light, and a means to arrange the composition layer which emits yellow light to the 1st [by the side of a substrate] barrier layer side can be illustrated. On the contrary, it is desirable to remove a monocrystal substrate, and to, arrange originally, the luminous layer composition layer which brings about luminescence of long wavelength most for example, in the position which serves as remoteness most from a monocrystal substrate, if it is in LED which takes out luminescence from the monocrystal substrate side which existed.

[0015]It is in the composition layer which constitutes a luminous layer, and the 1st luminous layer composition layer is tentatively called to the composition layer provided in the side nearest to the 1st barrier layer that consists of a Lynn-ized boron system semiconductor layer of the 1st conduction type by this invention. This 1st luminous layer composition layer consists of crystal layers which consist of a group III nitride semiconductor which contains Lynn (P) especially. In the group III nitride semiconductor containing Lynn (P) which is suitable as 1st luminous layer composition layer. Phosphorus nitride-ized gallium indium ($Ga_XIn_{1-X}P_{1-Y}N_Y$:0 <=X <=1, 0< Y<1), phosphorus nitride-ized gallium ($GaP_{1-Y}N_Y$:0<Y<1), etc. can be illustrated. In the group III nitride semiconductor layer containing these Lynn (P), by changing the presentation of Lynn (P) severalpercent slightly, a band gap can be changed and a luminous wavelength can be changed. That is, there is an advantage which can constitute two or more luminous layer composition layers which give luminescence of a multi-wavelength only from giving a slight change to the Lynn presentation. When gallium (Ga) of an III fellows composing element and the composition ratio of indium (In) are the same, generally a band gap decreases with increase of the composition ratio of Lynn (P). Therefore, it becomes convenient for obtaining the luminous layer composition layer of long wavelength.

[0016]The 1st luminous layer composition layer containing Lynn (P) laminated on the 1st barrier layer (cladding layer) constituted from a Lynn-ized boron system semiconductor layer, Since it becomes surface surface smoothness and continuity with the thing excellent in wealth, it can use effectively as a well (well) layer which makes quantum well (QuantumWell:QW) structure, for example. Especially the 1st luminous layer composition layer that consists of a transited [directly] type semiconductor material can be used for dominance as a well layer which brings about high luminescence intensity. If the 1st luminous layer composition layer is laminated as a well layer to the barrier layer which consists of the 1st Lynn-ized boron system semiconductor layer, the luminous layer of single (single) or multiplex (multi) quantum well

structure which makes an end a well layer can be constituted. Being in this invention, each well layer which constitutes multiple quantum well structure (MQW) constitutes a band gap from a different group III nitride semiconductor material. Although each well layer may be constituted from a mutually different group III nitride semiconductor material, the conduction type of each well layer is coincided with the conduction type of the 1st luminous layer composition layer. Other ends of QW structure, i.e., a termination, can consist of all of the barrier layer (barrier layer) to a well layer or a well layer. Although it is in the MQW structure which makes a luminous layer composition layer and a barrier (barrier) layer stratify periodically by turns, and a barrier layer has the same conduction type as a luminous layer composition layer and it constitutes from a semiconductor layer of a bigger band gap than a luminous layer composition layer, of course, it is desirable.

[0017]It is in the group III nitride semiconductor layer containing Lynn (P) which makes the 1st luminous layer composition layer, and if the Lynn (P) concentration in a layer is based on factors, such as diffusion, and fluctuates, a band gap will also change along with it. According to a 2nd embodiment of this invention, the interlayer who was formed on the surface of the undoped phosphorus-ized boron system semiconductor layer which makes the 1st barrier layer and who consists of group III nitride semiconductors is joined, and the 1st luminous layer composition layer is provided. Lynn which carries out thermal diffusion to a luminous layer from the Lynn-ized boron system semiconductor layer in which an interlayer makes the 1st barrier layer -- Lynn which captures (P) or boron (B) and invades into a luminous layer -- the duty which prevents the quantity of (P) or boron (B) increasing to ** is achieved. For example, when a silicon single crystal (silicon) is used as a substrate, it has the operation to which the silicon (Si) separated from the substrate blocks invading and causing change to carrier concentration into a luminous layer. That is, an interlayer has the operation which deters it being based on a foreign atom and changing a band gap and carrier concentration about the luminous layer which has the forbidden band that luminescence of desired wavelength is obtained, for example, and has suitable carrier concentration to bring about luminescence of high intensity. Since it is supposing that the 1st barrier layer of the ground of a luminous layer is constituted from a undoped phosphorus-ized boron system semiconductor layer in this invention, an interlayer, It utilizes for Lynn (P) which constitutes the 1st barrier layer or boron (B), and the purpose of controlling **** diffusion into the luminous layer of Lynn (P) especially, from dopant (dopant) of the 1st barrier layer.

[0018]When the thermal diffusion of Lynn (P) laminates a luminous layer under hot growing environment on the undoped phosphorus-ized boron system semiconductor layer which makes the 1st barrier layer, it happens notably. For example, as for an interlayer's thickness, although the long temperature of a gallium nitride indium luminous layer is 650 ** - 950 ** in general, if they takes an example, in order not to make ** increase the quantity of the concentration of Lynn which invades into a luminous layer, it is desirable about to be referred to as about 20 nm - about 500 nm. In order to prevent diffusion of the impurity from the interlayer itself to the inside of a luminous layer or the 1st barrier layer, it is undoped, and an interlayer is a high grade and it is optimal to constitute from a conductive semiconductor layer which does not include Lynn, especially a group III nitride semiconductor layer. On the relation which constitutes a luminous layer from a group III nitride semiconductor, if an interlayer is similarly constituted from a group III nitride semiconductor, a luminous layer [****] without a gap can be obtained simple. If it is constituting an interlayer from a conductive group III nitride semiconductor layer which can form membranes at low temperature from the growing temperature of the Lynn-ized boron system semiconductor layer, effect can be achieved from the 1st barrier layer to decrease the concentration of Lynn diffused to a luminous layer. As a material for constituting a concrete interlayer, gallium aluminum nitride ($\text{aluminum}_X Ga_{1-X}N$:0 <=X <=1) can be illustrated.

[0019]At a 3rd embodiment of this invention, it constitutes from a group III nitride semiconductor which has a band gap more than the group III nitride semiconductor which constitutes the 1st luminous layer composition layer for an interlayer. For example, there is an example which constitutes an interlayer from $\text{aluminum}_X Ga_{1-X}N$ (0< X<=1) about the 1st luminous layer composition layer that consists of $GaP_{1-Y}N_Y$ (0< Y<1). The interlayer of the band gap exceeding the 1st luminous layer composition layer can act as a barrier (barrier) layer to the 1st luminous layer composition layer. That is, if it carries out based on the laminated constitution of such an interlayer and the 1st luminous layer composition layer, the luminous layer of the quantum well structure which uses a barrier layer as an end can be constituted. Although any of the 1st or 2nd conduction type may be sufficient as an interlayer's conduction type, it is desirable to suppose that it is the same as that of the 1st luminous layer composition layer. An interlayer's band gap is larger than the 1st luminous layer composition layer, and when less than it of the 1st barrier layer is used, it is in LED and an effect is, for example to reduce forward voltage (what is called V_f). Via the interlayer who consists of $Ga_X In_{1-X}N$ which sets a room temperature band gap to 2.8 eV on the 1st barrier layer that consists of Lynn-ized boron (BP) of the monomer which sets the forbidden band in a room temperature to 3.0 eV as a suitable example of composition, The example which laminates the 1st luminous layer composition layer that sets a room temperature band gap to 2.6 eV can be given.

[0020]If it is constituting from a group III nitride semiconductor containing the element (composing element) which constitutes the group III nitride semiconductor layer which makes the 1st luminous layer composition layer for the interlayer who becomes a ground of the 1st luminous layer composition layer, it will become effective in obtaining the 1st luminous layer composition layer with continuity without a gap. It can depend on the work as a "growth core" of the composing element of the 1st luminous layer composition layer included in the interlayer, and membrane formation of the 1st luminous layer composition layer can be advanced smoothly. There is an example which provides the luminous layer composition layer which consists of phosphorus nitride-ized gallium indium ($Ga_X In_{1-X}P_{1-Y}N_Y$:0 <=X <=1, 0< Y<1) as a good example of a 4th embodiment of this invention, for example on the interlayer who consists of gallium nitride (GaN). it comes out of a luminous layer composition layer and especially the luminous layer that emits short wavelength light chiefly to constitute from a big group III nitride semiconductor of a band gap, etc. The forming temperature of a group III nitride semiconductor layer is about 700 ** - about 1200 **, and an elevated temperature. For this reason, it is preferred

for an interlayer to constitute from group III nitride semiconductor material of a high-melting point which does not deteriorate at the time of membrane formation of the group III nitride semiconductor layer in an elevated temperature.
[0021]If it has composition which provides the 2nd barrier layer that consists of a undoped phosphorus-ized boron system semiconductor of the 2nd conduction type in the surface of the luminous layer composition layer which makes the outermost layer of a luminous layer, the 1st barrier layer pinches ** and a luminous layer, and can constitute the light-emitting part of pn junction type DH structure. In a 5th embodiment of this invention, the 2nd barrier layer as well as the 1st barrier layer for example, $B_{alpha}aluminum_{beta}\ Ga_{gamma}In_{1-alpha\ .-.\ beta\ .-.\ gamma}P_{1-delta}As_{delta}$. (0< alpha<=1, 0<=beta<1, 0<=gamma<1, 0<alpha+beta+gamma<=1, 0<=delta<1) $B_{alpha}aluminum_{beta}Ga_{gamma}In_{1-alpha-beta-gamma}P_{1-delta}N_{delta}$ (0< alpha<=1, 0<=beta<1, 0<=gamma<1, and 0<alpha+beta+gamma<=1.) It constitutes from Lynn-ized boron system semiconductors, such as 0<=delta<1. The 2nd barrier layer constitutes conduction type from a undoped phosphorus-ized boron system semiconductor layer made opposite with the 1st barrier layer. For example, the 2nd barrier layer consists of undoped n form Lynn-ized boron system semiconductors to the 1st barrier layer of p form. In the Lynn-ized boron system semiconductor, there is an advantage to which the semiconductor layer which does not add intentionally the impurity which controls conduction type (= doping) but, in which ** also has the conductivity of the 1st or 2nd conduction type is brought. Therefore, if the 2nd barrier layer is formed from a undoped phosphorus-ized boron system semiconductor layer, complicated doping operation in which it is necessary to change into conduction type the impurity kind therefore added can be avoided, and the 2nd barrier layer that moreover has conductivity by low resistance simple can be constituted.
[0022]In providing the undoped phosphorus-ized boron system semiconductor layer which makes the 2nd barrier layer on the outermost layer of the luminous layer constituted from a group III nitride semiconductor layer, If it is providing the 2nd barrier layer on the outermost layer of the luminous layer which consists of a group III nitride semiconductor of the 1st or 2nd conduction type containing Lynn (P), the 2nd barrier layer that is excellent in continuity without a gap will be obtained. It is in the luminous layer composition layer which constitutes a luminous layer, and the composition layer which makes the surface of a luminous layer is called outermost layer of a luminous layer. As a good example of a 6th embodiment of this invention, the outermost layer of the luminous layer which consists of transited [directly] type n form $GaN_{1-Y}P_Y$ is joined, and the composition which provides the 2nd barrier layer that consists of a undoped n form Lynn-ized boron (BP) layer can be mentioned. Unlike the conventional group III nitride semiconductor, the mobility of an electron and an electron hole is not [Lynn-ized boron (BP)] extraordinarily different. That is, the diffusion length of both careers does not have a difference like a group III nitride semiconductor. Therefore, strict restriction is not added to the built-up sequence of a luminous layer composition layer like the former. However, it is in LED of the method which passes the 2nd barrier layer and takes out luminescence to the exterior, for example, and, as for the outermost layer of a luminous layer, it is desirable to constitute from a luminous layer composition layer which brings about luminescence of the shortest wavelength as compared with other luminous layer composition layers. That is, it is in LED of this method and it is necessary to consider the Lynn (P) content of a group III nitride semiconductor layer which makes the outermost layer of a luminous layer, or the Lynn presentation as the content or the presentation which gives the shortest luminous wavelength. The Lynn composition ratio (Y), respectively For example, Y_1, Y_2, Y_3. GaN[of three layers] $_{1-Y}P_Y$ ($Y=Y_1$.) set to ($0<=Y_1<Y_2<Y_3<=0.15$ [however,]) A Y_2 and Y_3 layer is made to stratify, and it is in constituting a luminous layer, and the band gap of the outermost layer of a luminous layer is the largest, therefore it consists of $GaN_{1-Y1}P_{Y1}$ layers which bring about luminescence of short wavelength most.
[0023]
[Function]Lynn (P) contained in the 1st luminous layer composition layer provided in contact with [these days] the undoped phosphorus-ized boron system semiconductor layer which makes the 1st barrier layer, It has the operation which decreases the band gap of a group III nitride semiconductor layer which makes the 1st luminous layer composition layer, and can contribute for constituting the 1st luminous layer composition layer that brings about luminescence of long wavelength from this.
[0024]The interlayer who consists of a group III nitride semiconductor formed in the middle of the undoped phosphorus-ized boron system semiconductor layer and the 1st luminous layer composition layer which make the 1st barrier layer, Lynn (P) diffused in the 1st luminous layer composition layer from the Lynn-ized boron system semiconductor layer which makes the 1st barrier layer is caught, and the operation which maintains the Lynn (P) concentration inside a luminous layer and a presentation is carried out.
[0025]The luminous layer composition layer which consists of a group III nitride semiconductor of the 1st or 2nd conduction type containing Lynn (P) which constitutes the outermost layer of the luminous layer which makes it come to stratify two or more composition layers, It has the operation which brings about the 2nd barrier layer that consists of a undoped phosphorus-ized boron system semiconductor of the 2nd conduction type that is excellent in continuity without a gap.
[0026]
[Example](The 1st working example) The case where LED of a pn junction type hetero structure provided with the luminous layer which consists blue glow and yellow light of a two-layer luminous layer composition layer which emits light respectively is created is made into an example, and the contents of this invention are explained concretely.
[0027]The mimetic diagram of LED1B concerning the 1st working example is shown in drawing 1. The cross section of LED1B in alignment with dashed line X-X' shown in drawing 1 is shown in drawing 2.
[0028]The laminated structure body 1A of the LED1B use formed the p form (111)-Si single crystal in which boron (B) was added as the substrate 101. On the substrate 101, Lynn (P) which makes an amorphous substance a subject in the

state of as-grown, and the buffer layer 102 containing boron (B) were deposited at 450 ** by boron triethyl (C_2H_5) $(_3B)$ / phosphine (PH_3) / the hydrogen (H_2) system ordinary pressure MOCVD method. The thickness of the buffer layer 102 could be 5 nm.

[0029]After ending membrane formation of the buffer layer 102, the temperature of the substrate 101 was raised at 1050 **. The 1st barrier layer 103 that is undoped and consists of a p boron [Lynn-ized] (BP) layer of type on the surface of the buffer layer 102 was made to laminate after temperature up using the above-mentioned MOCVD vapor-phase-epitaxy means. The thickness of p form Lynn-ized boron layer which makes the 1st barrier layer 103 set to about 450 nm, and carrier concentration was abbreviation 2×10^{19} cm^{-3}. The 1st barrier layer 103 constituted the band gap in the room temperature from p form Lynn-ized boron which shall be about 3 eV.

[0030]The temperature of the silicon single crystal board 101 was reduced at 800 **, circulating PH_3 and H_2 in a MOCVD growth reaction system, after ending the vapor phase epitaxy of the 1st barrier layer 103. Then, make it join on the 1st barrier layer 103, and by trimethylindium (CH_3) $(_3In)$ / ammonia (NH_3) / $_{(CH_3)}3Ga/PH_3$ / the hydrogen (H_2) system ordinary pressure MOCVD method. n form phosphorus nitride-ized gallium indium $(Ga_{0.55}In_{0.45}N_{0.95}P_{0.05})$ layer which makes the 1st luminous layer composition layer 105-1 was provided. The Lynn presentation of the 1st luminous layer composition layer 105-1 was made into the ratio (=0.05) from which luminescence of a yellow belt is obtained, and thickness could be about 68 nm. On the 1st luminous layer composition layer 105-1, the 2nd luminous layer composition layer 105-2 that consists of an n form gallium nitride indium $(Ga_{0.90}In_{0.10}N)$ layer grown up at 800 ** by the above-mentioned ordinary pressure MOCVD method was formed. The thickness of the 2nd luminous layer composition layer 105-2 could be about 110 nm. The luminous layer 105 consisted of the 1st and the 2nd luminous layer composition layer 105-1, and 105-2.

[0031]After ending formation of the laminated structure body 1A, under [a fixed quantity / atomic percentage / inside the luminous layer 105 / Lynn (P) / it depends on a general secondary ion mass analysis method (SIMS) and]. The phosphorus atom concentration inside an abbreviation 8×10^{20} atom $/cm^3$, and the 2nd luminous layer composition layer 105-2 with average average phosphorus atom concentration inside the 1st luminous layer composition layer 105-1 was respectively quantified with an abbreviation 4×10^{19} atom / cm^3. From this, increase in quantity of some of the phosphorus atom concentration based on invasion of the Lynn (P) atom from the 1st barrier layer 103 was detected by the 1st and the 2nd luminous layer composition layer 105-1, and 105-2.

[0032]The surface electrode 107 which consists of three-layer layered structure of Au / nickel (nickel) / Au which has arranged the thin film layer which becomes a side in contact with the luminous layer 105 surface from gold (Au) was formed in the center section of the surface of the luminous layer 105. The surface electrode 107 which serves as the plinth (pad) electrode for connection was used as the circular electrode which shall be about 120 micrometers in diameter. To the approximately whole area of the rear face of p form Si single crystal substrate 101, the ohmic electrode which consists of a vacuum evaporation film of an aluminum antimony (aluminum-Sb) alloy as the rear electrode 108 has been arranged, and LED1B was constituted in it. The thickness of the aluminum-Sb vacuum evaporation film could be about 2 micrometers. After forming the surface electrode 107 and the rear electrode 108, the Si single crystal substrate which makes the substrate 101 is judged in the direction parallel to the [211] directions, and vertical, The silicon single crystal 101 of the square which sets one side to about 350 micrometers constituted LED1B of the pn junction type hetero structure of the method which takes out luminescence from the surface of an opposite hand to the exterior.

[0033]When conduction of the actuating current of 20 mA (mA) was carried out between the surface electrode 107 and the rear electrode 108 in a forward direction, yellowish white light was emitted from LED1B. The spectral component of yellowish white light was with the yellow light which sets the center wavelength corresponding to luminescence from the 1st luminous layer composition layer 105-1 to 570.5 nm, and the blue glow which sets the center wavelength corresponding to luminescence from the 2nd luminous layer composition layer 105-2 to 481.5 nm, as shown in drawing 3. The luminosity in a chip (chip) state of LED1B which brings about two waves of different luminescence measured using a common integrating sphere became a 5-mcd (mcd), and the white light emitting diode of high luminescence intensity was provided. forward voltage (V_f, however forward current = 20 mA) -- about -- it is 2.9V and reverse voltage (V_R, however reverse current =10microA) became more than 5V.

[0034](The 2nd working example) In the 2nd working example, a description in the 1st above-mentioned working example is undoped, the case where LED2B is constituted from the laminated structure body 2A which made it join to the 1st barrier layer 103 that consists of Lynn-ized boron (BP) of p form, and formed the interlayer 104 is made into an example, and the contents of this invention are explained.

[0035]The cross section of LED2B concerning the 2nd working example is shown in drawing 4. Components other than interlayer 104 are made the same as that of the 1st above-mentioned working example. Therefore, in drawing 4, about the same component, the same numerals are attached and the explanation is abbreviated to having been shown in drawing 1 and drawing 2.

[0036]The interlayer 104 was undoped and consisted of gallium nitride indium $(Ga_{0.95}In_{0.05}N)$ layers of n form. the $Ga_{0.95}In_{0.05}N$ interlayer 104 who sets indium (In) composition ratio to 0.05 (= 5%) -- a $_{(CH_3)}3Ga/(CH_3)$ $_3In/NH_3/H_2$ system -- vapor phase epitaxy was carried out at 800 ** by the ordinary pressure MOCVD method. The interlayer's 104 thickness was set as about 25 nm. The interlayer's 104 carrier concentration was estimated to be abbreviation 2×10^{18} cm^{-3}. The interlayer 104 constituted the band gap in the room temperature from $Ga_{0.95}In_{0.05}N$ of the wurtzite crystal

form which shall be about 3.2 eV.

[0037]On the interlayer 104, the same luminous layer composition layer 105-1 of composition as having indicated in the 1st above-mentioned working example and the luminous layer 105 which consists of 105-2 were joined, it provided, and formation of the laminated structure body 2A was ended. if it depends on a general secondary ion mass analysis method (SIMS) -- the Lynn (P) atomic percentage inside the interlayer 104 -- about -- it was quantified with a $4x10^{19}$ atom / cm^{3}. The phosphorus atom concentration inside [105 to luminous layer composition layer 1] the 1st is an abbreviation $8x10^{18}$ atom / cm^{-3}, and the phosphorus atom concentration inside the 2nd luminous layer composition layer 105-2 became less than it. Incidentally in the 1st luminous layer composition layer 105-1 that joined to the 1st barrier layer 103 and was directly provided in it, without forming the interlayer 104 in the 1st above-mentioned working example like a description. If it takes into consideration that the phosphorus atom concentration of the inside was the high concentration of an abbreviation $8x10^{20}$ atom / cm^{3}, the interlayer 104 concerning this invention, Capturing the Lynn (P) atom diffused from the 1st barrier layer 103, and becoming effective in maintaining the Lynn composition ratio of the 1st luminous layer composition layer 105-1 was shown. It depends on the capture operation of boron (B) or the Lynn (P) atom diffused from the 1st barrier layer 103 by the interlayer 104, Disorderly-ization of the heterojunction interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 brought a result deterred (refer to the work for opto-electronics common research institutes, "the basic technology of an optoelectronic integrated circuit" (August 20, 1989, Ohm-Sha Issue, the 1st edition 1st printing), 371 - 384 pages).

[0038]The same surface electrode 107 and the rear electrode 108 as what was indicated in the 1st working example were formed, and LED2B was constituted. When conduction of the 20-mA actuating current was carried out between the surface electrode 107 and the rear electrode 108 in a forward direction, blue white light was emitted. The spectral component of blue white light was with the yellowish green light which sets the center wavelength corresponding to luminescence from the 1st luminous layer composition layer 105-1 to 566.0 nm, and the blue glow which sets the center wavelength corresponding to luminescence from the 2nd luminous layer composition layer 105-2 to 475.4 nm. The luminosity in the chip state of LED2B which brings about two waves of different luminescence measured using a common integrating sphere was set to about 5 mcd(s), and the white light emitting diode of high luminescence intensity was provided. disorderly-ization of the joining interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 was controlled -- a sake -- a good rectifying action -- manifesting oneself -- having -- forward voltage (V_f, however forward current = 20 mA) -- about -- it is 3.0V and reverse voltage (V_R, however reverse current =10microA) became more than 8V.

[0039](The 3rd working example) In the 3rd working example, the case where the interlayer 104 is constituted from group III nitride semiconductor material which is different from $Ga_{0.95}In_{0.05}N$ of a description in the 2nd above-mentioned working example is made into an example, and the contents of this invention are explained. Components other than interlayer 104 are made the same as that of the 1st above-mentioned working example and the 2nd working example.

[0040]The cross section of LED3B concerning the 2nd working example is shown in drawing 5. In drawing 5, about the same component, the same numerals are attached and the explanation is abbreviated to having been shown in drawing 1 thru/or drawing 3.

[0041]The interlayer 104 was undoped and consisted of gallium nitride (GaN) layers of n form. the interlayer 104 -- a $(CH_3)_3Ga/NH_3/H_2$ system -- vapor phase epitaxy was carried out to the case of the 1st barrier layer 103 at 1050 ** of the ** by the ordinary pressure MOCVD method. The interlayer's 104 thickness was set as about 30 nm. The interlayer's 104 carrier concentration was estimated to be abbreviation $2x10^{18}$ cm^{-3}. The interlayer 104 constituted the band gap in the room temperature from GaN of the wurtzite crystal form which shall be about 3.4 eV.

[0042]In the 3rd working example, the interlayer 104 was used as a barrier (barrier) layer to the luminous layer 105 again in view of constituting the interlayer 104 from a group III nitride semiconductor which makes a band gap larger than the case of the 2nd working example. The two-layer luminous layer composition layer 105-1 which is different from the 1st working example in the luminous wavelength of a description, and 105-2 were made to stratify one by one on the GaN layer which is also the interlayer 104 who made it join to the 1st barrier layer 103, and provided, and is also the lower barrier layer 104-1. the 2nd luminous layer composition layer 105-2 top -- a $(CH_3)_3Ga/NH_3/H_2$ system -- vapor phase epitaxy was carried out at 800 ** by the ordinary pressure MOCVD method as well as the luminous layer composition layer 105-1 and -2 -- it was undoped and the GaN layer of n form was joined as the top barrier layer 104-2. Carrier concentration of the top barrier layer 104-2 was made into abbreviation $5x10^{18}$ cm^{-3}, and thickness could be about 300 nm.

[0043]if it depends on a general secondary ion mass analysis method (SIMS), the average Lynn (P) atomic percentage inside the interlayer 104 is lower than the case of the 2nd working example -- about -- it was quantified with a $1x10^{18}$ atom / cm^{3}. The average phosphorus atom concentration inside [105 to luminous layer composition layer 1] the 1st is an abbreviation $4x10^{18}$ atom / cm^{-3}, and became equivalent [the phosphorus atom concentration inside the 2nd luminous layer composition layer 105-2] to it. If it depends on the section TEM observation using a transmission electron microscope (TEM), The presentation steepness in the heterojunction interface of the interlayer 104 (lower barrier layer 104-1) and the 1st luminous layer composition layer 105-1 is good, and it was accepted that disorderly-ization of the

heterojunction interface based on Lynn (P) and boron (B) which are diffused from the 1st barrier layer 103 is deterred.
[0044]The same surface electrode 107 and the rear electrode 108 given in the 1st working example as a thing were formed in the approximately whole area of the surface of the top barrier layer 104-2 which makes the outermost layer of the laminated structure body 3A, and the rear face of the silicon single crystal board 101, respectively, and LED3B was constituted in it. White light was emitted when conduction of the 20-mA actuating current was carried out between the surface electrode 107 and the rear electrode 108 in a forward direction. When depending on the general spectrophotometry means, the spectral component of white light was with the yellowish green light which sets the center wavelength corresponding to luminescence from the 1st luminous layer composition layer 105-1 to 565.0 nm, and the blue glow which sets the center wavelength from the 2nd luminous layer composition layer 105-2 to 472.2 nm. The luminosity in the chip state of LED3B which brings about two waves of different luminescence measured using a common integrating sphere was set to about 5 mcd(s), and the white light emitting diode of high luminescence intensity was provided. As for luminescence intensity, a difference was hardly accepted to be LED2B given in the 2nd working example. However, about 10 nm of half breadth (FWMH) of each of above-mentioned spectral components has become small as compared with the case of the 2nd working example by considering it as the structure of providing the barrier layer 104-1 and 104-2 in the upper and lower sides of the luminous layer 105.
LED which is excellent in monochromaticity will be provided.
disorderly-ization of the joining interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 was controlled -- a sake -- a good rectifying action -- manifesting oneself -- having -- forward voltage (V_f, however forward current = 20 mA) -- about -- it being 3.0V and, reverse voltage (V_R, however reverse current =10microA) -- about -- it was set to 9V, and LED3B of high withstand pressure was provided collectively.
[0045](The 4th working example) The case where LED is constituted using the interlayer who consists of a different group III nitride semiconductor from the 3rd above-mentioned working example is made into an example, and the contents of this invention are explained concretely. The section structure of LED concerning the 4th working example is as being shown in drawing 5, and differs only in the interlayer's 104 component found in the figure.
[0046]In the 4th working example, the interlayer 104, The 1st luminous layer of a description in the 1st working example. It constituted from a gallium-aluminum-nitride mix crystal ($aluminum_{0.02}Ga_{0.98}N$) of being undoped and n form containing gallium (Ga) and nitrogen (N) which are composing elements of the $Ga_{0.55}In_{0.45}N_{0.95}P_{0.05}$ layer to make. the interlayer of this invention -- a 1st barrier layer top -- a trimethylaluminum (CH_3) ($_3$aluminum) / (CH_3) $_3Ga/NH_3/H_2$ system -- vapor phase epitaxy was carried out to the case of the 1st barrier layer at 1050 ** of the ** by the ordinary pressure MOCVD method. The interlayer's thickness was set as about 30 nm. The interlayer's carrier concentration was estimated to be abbreviation $3x10^{17}$ cm^{-3}. The interlayer constituted the band gap in the room temperature from $aluminum_{0.02}Ga_{0.98}N$ of the wurtzite crystal form which shall be about 3.4 eV.
[0047]On the interlayer, the same luminous layer and top barrier layer given in the 3rd above-mentioned working example as a thing were provided by conditions given in the 3rd working example. Since the interlayer of this example 4 had the 1st thru/or a bigger band gap than which an interlayer given in the 3rd working example and also contained the composing element of the 1st luminous layer composition layer, especially the 1st luminous layer composition layer made the surface flat, it became what is excellent in continuity. Since the surface of the 1st luminous layer composition layer turned into a mirror plane which is excellent in smooth nature, it became a continuation film which excels [layer / 2nd / that the layer was made to stratify / luminous layer composition] in surface surface smoothness. In observation of the surface state which depends on a differentiation interference pattern optical microscope and a scanning electron microscope (SEM), most the gaps or stomata (pit) which spoil the continuity of a layer were not recognized visually by the surface of the 2nd luminous layer composition layer.
[0048]Like the 3rd above-mentioned working example, the surface electrode and the rear electrode were formed and LED was constituted. When conduction of the 20-mA actuating current was carried out between a surface electrode and a rear electrode in a forward direction, white light was emitted like the case of the 3rd working example. about 10 nm of half breadth of each emission-spectrum ingredient is smallness as well as LED given in the 3rd working example as compared with the case of the 2nd working example -- it was 20 nm about. On the other hand, in the 4th working example, the luminosity in the chip state was set to about 7 mcd(s) reflecting the luminous layer composition layer which is excellent in a surface state having been brought about by constituting an interlayer from a group III nitride semiconductor containing the composing element of the 1st luminous layer composition layer. The luminosity measured using this common integrating sphere is about 1.5 times the LED given in the 3rd working example.
The higher-intensity white light emitting diode was provided.
Since disorderly-ization of the joining interface of an interlayer and the 1st luminous layer composition layer was controlled, a good rectifying action manifests itself -- forward voltage (V_f, however forward current = 20 mA) -- about -- being set to 3.0V -- reverse voltage (V_R, however reverse current =10microA) -- about -- it was set to 9V, and LED of high withstand pressure was provided collectively.
[0049](The 5th working example) On the luminous layer which was made to stratify two or more luminous layer composition layers which bring about luminescence which is different in wavelength in this example 5, and was formed, The case where LED of a pn junction type DH structure provided with the 2nd barrier layer that consists of a undoped phosphorus-ized boron system semiconductor of the 2nd conduction type is constituted is made into an example, and the contents of this invention are explained concretely.
[0050]The section structure of LED4B concerning the 5th working example is typically shown in drawing 6. It is in LED4B shown in drawing 6, and about the same component, the same numerals are attached and the explanation is abbreviated

to having indicated in the 1st above-mentioned working example.
[0051]In the 5th working example, after ending growth of the luminous layer 105 at 800 ** on the interlayer 104 like a description in the 4th above-mentioned working example, temperature up of the temperature of the silicon single crystal board 101 was carried out to 850 ** in the mixed atmosphere of NH_3 and H_2. After temperature up, it was undoped, and the 2nd barrier layer 106 that consists of Lynn-ized boron (BP) of the monomer of n form was joined to the luminous layer 105, and it provided in it. the 2nd barrier layer 106 -- a $(C_2H_5)_3B/PH_3/H_2$ system -- it was made to grow up by the ordinary pressure MOCVD method The thickness of the 2nd barrier layer 106 could be the 1st barrier layer 103 and 450 nm same in abbreviation. In order to make the 2nd barrier layer 106 act as a luminous transmission layer for taking out luminescence from the luminous layer 105 to the exterior efficiently, it constituted the band gap in the room temperature from undoped phosphorus-ized boron which shall be about 3 eV.
[0052]the Lynn (P) atomic percentage which depends on a general secondary ion mass analysis method (SIMS) and whose inside of the interlayer 104 is average after ending formation of the laminated structure body 4A -- about -- it was quantified with a $4x10^{18}$ atom / cm^3. The average phosphorus atom concentration inside [105 to luminous layer composition layer 1] the 1st is an abbreviation $2x10^{18}$ atom / cm^{-3}, and the phosphorus atom concentration inside the 2nd luminous layer composition layer 105-2 became less than it. It depended on the capture operation of boron (B) or the Lynn (P) atom diffused from the 1st barrier layer 103 by the interlayer 104, and being deterred depended on section TEM technique and disorderly-ization of the heterojunction interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 was accepted.
[0053]It was undoped and the surface electrode 107 has been arranged in the center section of the surface of the 2nd barrier layer 106 of n form. The surface electrode 107 constituted the side in contact with the 2nd barrier layer 106 from Au-germanium / nickel (nickel) / a three layers of Au(s) multistory film used as gold and a germanium (Au-germanium) alloy film. The diameter of the circular surface electrode 107 which serves as a pedestal electrode was about 110 micrometers. In the approximately whole area of the rear face of p form Si single crystal substrate 101, the ohmic electrode which consists of aluminum (aluminum) as the rear electrode 108 has been arranged, and LED4B was constituted in it. The thickness of aluminum vacuum deposition film could be about 3 micrometers. After forming the surface electrode 107 and the rear electrode 108, Si single crystal 101 was cut out in the direction parallel to the [211] directions, and vertical, and the silicon single crystal 101 of the square which sets one side to about 350 micrometers constituted LED4B of the method which takes out luminescence from the 2nd barrier layer 106 side of an opposite hand to the exterior.
[0054]When conduction of the 20-mA actuating current was carried out between the surface electrode 107 and the rear electrode 108 in a forward direction, the 2nd barrier layer 106 was mainly passed and blue white light was emitted from LED4B. The emission-spectrum ingredient of blue glow was the same as that of abbreviation [showed / in drawing 3]. LED4B of the 5th working example wrote with the light-emitting part of pn junction type DH heterojunction structure, and the luminosity measured using a common integrating sphere was set to about 10 mcd(s), and has provided the white light emitting diode of high luminescence intensity. disorderly-ization of the joining interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 was controlled -- a sake -- a good rectifying action -- manifesting oneself -- having -- forward voltage (V_f, however forward current = 20 mA) -- about -- it is 3.2V and reverse voltage (V_R, however reverse current =10microA) became more than 5V.
[0055](The 6th working example) The case where LED of pn junction type DH structure which provides a undoped phosphorus-ized boron system semiconductor layer as the 2nd barrier layer on the luminous layer composition layer containing Lynn (P) which makes the outermost layer of a luminous layer is constituted is made into an example, and the contents of this invention are explained concretely.
[0056]LED concerning the 6th working example is as section structure showing drawing 6 as well as the 5th working example of the above.
LED of the 5th working example differs only in the component of the outermost layer (2nd luminous layer composition layer 105-2) of a luminous layer.

[0057]The 6th working example constituted the 2nd luminous layer composition layer 105-2 from the phosphorus nitride-ized gallium indium ($Ga_{0.90}In_{0.10}N_{0.97}P_{0.03}$) layer. the 2nd luminous layer composition layer 105-2 -- a $(CH_3)_3Ga/(CH_3)_3In/NH_3/PH_3/H_2$ system -- it was made to grow up at 800 ** by the ordinary pressure MOCVD method as well as the 1st luminous layer composition layer 105-1 The thickness of the 2nd luminous layer composition layer 105-2 was set as about 65 nm.
[0058]In accordance with the technique given in the 5th above-mentioned working example, in the surface of the 2nd luminous layer composition layer 105-2, it was undoped, and the 2nd barrier layer 106 that consists of Lynn-ized boron of n form was laminated on it. In the 6th working example, since the 2nd luminous layer composition layer 105-2 that contains Lynn (P) for the 2nd barrier layer 106 was formed as a ground, the barrier layer which is excellent in surface smooth nature especially was brought about. From the surface observation which depends on SEM, most of a gap or a pit was not recognized visually by the 2nd barrier layer 106, but it was checked that they are continuous layers. Then, it had the same composition with having indicated in the 5th working example, the surface electrode 107 and the rear electrode 108 were formed, and LED was constituted.
[0059]When conduction of the 20-mA actuating current was carried out between the surface electrode 107 and the rear electrode 108 in a forward direction, the 2nd barrier layer 106 was mainly passed and blue white light was emitted from

LED. The emission-spectrum ingredient of blue glow was the same as that of abbreviation [showed / in drawing 3]. The luminosity of LED measured using a common integrating sphere was set to about 10 mcd(s), and has provided the white light emitting diode of high luminescence intensity. Although disorderly-ization of the joining interface of the interlayer 104 and the 1st luminous layer composition layer 105-1 is controlled, in addition, since the 2nd barrier layer 106 was constituted from a undoped n form Lynn-ized boron layer which is excellent in continuity, forward voltage (V_f, however forward current = 20 mA) -- about -- it is 3.0V and LED which reverse voltage (V_R, however reverse current =10microA) presents the pn junction characteristic superior to more than 7V and LED of the 5th working example was provided.
[0060]
[Effect of the Invention]The substrate which will consist of crystals if it depends on this invention, and the 1st barrier layer that were provided on the substrate and that is undoped and consists of a Lynn-ized boron system semiconductor of the 1st conduction type, . Make it come to stratify two or more composition layers which were provided on the 1st barrier layer and which consist of a group III nitride semiconductor which is mutually different in a band gap. In the pn junction type compound semiconductor light emitting element provided with the luminous layer of the 1st or 2nd conduction type, Since the composition layer (1st luminous layer composition layer) of the luminous layer provided in the side nearest to the 1st barrier layer is constituted from a group III nitride semiconductor of the 1st or 2nd conduction type containing Lynn (P), The pn junction type compound semiconductor light emitting element which can constitute 1 composition layer of luminous layers which bring about luminescence of long wavelength comparatively, such as yellow belt light, simple, therefore presents luminescence of a multi-wavelength can be provided simply.
[0061]When depending on this invention, since the interlayer who was formed on the surface of the 1st barrier layer that consists of a undoped phosphorus-ized boron system semiconductor layer and who consists of group III nitride semiconductors is joined and the 1st luminous layer composition layer is provided, The pn junction type compound semiconductor light emitting element which could maintain the Lynn composition ratio of the 1st luminous layer composition layer to the request therefore where the luminous wavelength was stabilized by operation of the interlayer who captures Lynn which carries out thermal diffusion from the 1st barrier layer to the 1st luminous layer composition layer can be provided.
[0062]When depending on this invention, since it constitutes from a group III nitride semiconductor which has a band gap more than the group III nitride semiconductor which constitutes the 1st luminous layer composition layer for an interlayer especially, The pn junction type compound semiconductor light emitting element which could constitute the luminous layer of the quantum well structure which makes an interlayer a barrier layer simple, to which the mixed colors of the luminescent components which are excellent in monochromaticity were carried out and which brings about luminescence of a multi-wavelength can be provided.
[0063]When depending on this invention, since it constitutes from a group III nitride semiconductor containing the composing element of the group III nitride semiconductor layer which makes the 1st luminous layer composition layer for an interlayer especially, For example, it could obtain the 1st luminous layer composition layer that is excellent in surface surface smoothness and continuity and reflected the good pn junction characteristic, the pn junction type compound semiconductor light emitting element which is excellent in forward voltage or reverse voltage can be provided.
[0064]When depending on this invention, since the 2nd barrier layer that consists of a undoped phosphorus-ized boron system semiconductor layer of the 2nd conduction type is provided in the surface of the luminous layer composition layer which makes the outermost layer of a luminous layer and the light-emitting part of double heterojunction structure is constituted, The pn junction type compound semiconductor multicolor light emitting device which is excellent in luminescence intensity can be provided.
[0065]When depending on this invention, since the luminous layer composition layer which makes the outermost layer of a luminous layer is constituted from a group III nitride semiconductor of the 1st or 2nd conduction type including Lynn, The 2nd barrier layer can be formed from the undoped phosphorus-ized boron system semiconductor layer which is excellent in continuity, therefore the compound semiconductor multicolor light emitting device of the pn junction type double hetero structure of high luminescence intensity where forward voltage is low can be provided, for example.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1]It is a mimetic diagram of LED concerning the 1st working example of this invention.
[Drawing 2]It is a cross section in alignment with dashed line X-X' of LED shown in drawing 1.
[Drawing 3]It is an emission spectrum of LED concerning the 1st working example of this invention.
[Drawing 4]It is a cross section of LED concerning the 2nd working example of this invention.
[Drawing 5]It is a cross section of LED concerning the 3rd working example of this invention, and the 4th working example.
[Drawing 6]It is a cross section of LED concerning the 5th working example of this invention, and the 6th working example.
[Description of Notations]
1A, 2A, 3A, and 4A Laminated structure body
1B, 2B, 3B, 4B LED
101 Substrate
102 Buffer layer
103 The 1st barrier layer
104 Interlayer
104-1 Lower barrier layer
104-2 Top barrier layer
105 Luminous layer
105-1 The 1st luminous layer composition layer
105-2 The 2nd luminous layer composition layer
106 The 2nd barrier layer
107 Surface electrode
108 Rear electrode

[Translation done.]

(5)

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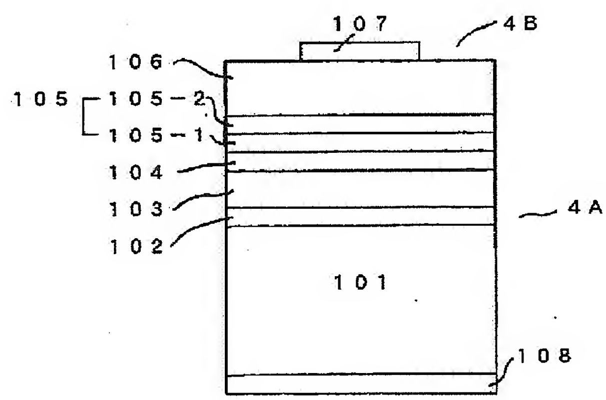
(54)【発明の名称】　ｐｎ接合型化合物半導体発光素子、その製造方法、白色発光ダイオード

(57)【要約】
【課題】多波長の発光を呈するｐｎ接合型化合物半導体発光素子を簡易に提供する。
【解決手段】基板上に設けられたアンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層と、第１の障壁層上に設けられた、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる発光層とを備えた発光素子に於いて、第１の障壁層に最も近い側に設ける発光層の構成層をリン（Ｐ）を含むＩＩＩ族窒化物半導体とする。



【特許請求の範囲】

【請求項１】結晶からなる基板と、基板上に設けられたアンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層と、第１の障壁層上に設けられた、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる、第１または第２の伝導形の発光層とを備えたｐｎ接合型化合物半導体発光素子に於いて、第１の障壁層に最も近い側に設ける発光層の構成層（第１の発光層構成層）が、リン（Ｐ）を含むＩＩＩ族窒化物半導体から構成されていることを特徴とするｐｎ接合型化合物半導体発光素子。

【請求項２】基板が、珪素（Ｓｉ）単結晶基板であることを特徴とする請求項１に記載のｐｎ接合型化合物半導体発光素子。

【請求項３】発光層の構成層が、窒化リン化ガリウム・インジウム（$Ga_X In_{1-X} P_{1-Y} N_Y$：０≦Ｘ≦１、０＜Ｙ＜１）または窒化リン化ガリウム（$GaP_{1-Y} N_Y$：０＜Ｙ＜１）からなることを特徴とする請求項１または２に記載のｐｎ接合型化合物半導体発光素子。

【請求項４】第１の障壁層が、発光層を構成する複数の発光層構成層の何れよりも、少なくとも０．１ｅＶ以上禁止帯幅を大とすることを特徴とする請求項１乃至３の何れか１項に記載のｐｎ接合型化合物半導体発光素子。

【請求項５】第１の障壁層の表面上にＩＩＩ族窒化物半導体からなる中間層が形成され、該中間層に接合させて第１の発光層構成層が設けられていることを特徴とする請求項１乃至４の何れか１項に記載のｐｎ接合型化合物半導体発光素子。

【請求項６】中間層が、第１の発光層構成層を構成するＩＩＩ族窒化物半導体以上の禁止帯幅を有するＩＩＩ族窒化物半導体から構成されていることを特徴とする請求項５に記載のｐｎ接合型化合物半導体発光素子。

【請求項７】中間層が、第１の発光層構成層をなすＩＩＩ族窒化物半導体を構成する元素を含むＩＩＩ族窒化物半導体から構成されていることを特徴とする請求項５または６に記載のｐｎ接合型化合物半導体発光素子。

【請求項８】発光層の最表層をなす発光層構成層の表面に、アンドープで第２の伝導形のリン化硼素系半導体からなる第２の障壁層が設けられていることを特徴とする請求項１乃至７の何れか１項に記載のｐｎ接合型化合物半導体発光素子。

【請求項９】発光層の最表層をなす発光層構成層が、リン（Ｐ）を含む第１または第２の伝導形のＩＩＩ族窒化物半導体から構成されていることを特徴とする請求項８に記載のｐｎ接合型化合物半導体発光素子。

【請求項１０】結晶からなる基板上に、アンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層を形成し、さらに該第１の障壁層上に、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる、第１または第２の伝導形の発光層を形成するｐｎ接合型化合物半導体発光素子の製造方法に於いて、第１の障壁層に最も近い側に設ける発光層の構成層（第１の発光層構成層）を、リン（Ｐ）を含むＩＩＩ族窒化物半導体から構成することを特徴とするｐｎ接合型化合物半導体発光素子の製造方法。

【請求項１１】第１の障壁層の表面上にＩＩＩ族窒化物半導体からなる中間層を形成し、該中間層に接合させて第１の発光層構成層を形成することを特徴とする請求項１０に記載のｐｎ接合型化合物半導体発光素子の製造方法。

【請求項１２】発光層の最表層をなす発光層構成層の表面に、アンドープで第２の伝導形のリン化硼素系半導体からなる第２の障壁層を形成することを特徴とする請求項１０または１１に記載のｐｎ接合型化合物半導体発光素子の製造方法。

【請求項１３】請求項１乃至９の何れか１項に記載のｐｎ接合型化合物半導体発光素子からなる白色発光ダイオード。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ｐｎ接合型化合物半導体発光素子に係り、特に多色発光のｐｎ接合型化合物半導体発光素子において、多波長の発光をもたらす複数の構成層を重層させてなる発光層を構成するための技術に関する。

【０００２】

【従来の技術】従来より、窒化ガリウム・インジウム（$Ga_X In_{1-X} N$：０≦Ｘ≦１）などのＩＩＩ族窒化合物半導体は、発光ダイオード（ＬＥＤ）において青色等の短波長光を出射するための発光層の構成材料として利用されている（特公昭５５－３８３４号公報参照）。$Ga_X In_{1-X} N$（０≦Ｘ≦１）では、ガリウム（Ｇａ）組成比（＝Ｘ）、同じくインジウム組成比（＝１－Ｘ）に対応して禁止帯幅（ｂａｎｄｇａｐ）が非線形的に急峻に変化することが知れている（上記の特公昭５５－３８３４号公報参照）。例えば、六方晶ウルツ鉱（Ｗｕｒｔｚｉｔｅ）結晶型の$Ga_X In_{1-X} N$では、インジウム組成を例えば、０．２とすることにより、室温での禁止帯幅を窒化ガリウム（ＧａＮ）の約３．４エレクトロンボルト（単位：ｅＶ）より約２．９ｅＶへと減ぜられる（上記の特公昭５５－３８３４号公報参照）。この様に、$Ga_X In_{1-X} N$（０≦Ｘ≦１）にあっては、インジウム組成比（＝１－Ｘ）の僅かに変化させることにより、発光波長に変化を与えられる利点が備えられている。

【０００３】従来の多色発光の発光素子では、発光波長を相違する多波長の発光をもたらす発光層を、インジウム組成（＝１－Ｘ）を相違する複数の窒化ガリウム・インジウム（$Ga_X In_{1-X} N$：０≦Ｘ≦１）層から構成する例が開示されている。例えば、特開２００１－１６８

３８４号公報（平成１３（２００１）年6月２２日公開）に記載の発明には、インジウム（Ｉｎ）組成を互いに異にする３層の$Ga_XIn_{1-X}N$（０≦Ｘ≦１）井戸（ｗｅｌｌ）層から多波長の発光をもたらす発光層を構成する技術が開示されている。また、例えば、特開平１１－２８９１０８号公報（平成１１（１９９９）年１０月１９日公開）の発明では、インジウム組成を相違する２層の$Ga_XIn_{1-X}N$（０≦Ｘ≦１）層を重層させて２波長の発光を呈するＬＥＤが構成されている。また、インジウム組成を相違する複数の$Ga_XIn_{1-X}N$（０≦Ｘ≦１）層を重層させてなる発光層を具備する多波長のＬＥＤは、特開平１０－２２５２５号公報（平成１０（１９９８）年1月２３日公開）の発明にも記載されている。

【０００４】従来の発光波長を相違する多波長の発光をもたらす発光層を備えた多色発光素子は、ｐｎ接合型ヘテロ（異種：ｈｅｔｅｒｏ）接合構造の発光部を有する構成となっている。特に、発光の強度の増大を果たすために、発光部は２重ヘテロ（<u>Ｄ</u>ｏｕｂｌｅ <u>Ｈ</u>ｅｔｅｒｏ：ＤＨ）構造となっている（寺本　巖著、「半導体デバイス概論」（１９９５年3月３０日、（株）培風館発行初版、１２４～１２５頁参照）。ＤＨ接合構造の発光部は、発光層と、それを中間に挟持するｎ形またはｐ形の障壁（ｃｌａｄ）層との接合構造から構成されている。従来の多色発光素子にあって、$Ga_XIn_{1-X}N$（０≦Ｘ≦１）発光層を挟持するクラッド層は、ｎ形またはｐ形の窒化アルミニウム・ガリウム（$Al_XGa_{1-X}N$：０≦Ｘ≦１）から構成されるのが通常である（上記の①特開２００１－１６８３８４号、②特開平１１－２８９１０８号、および③特開平１０－２２５２５号各公報参照）。

【０００５】

【発明が解決しようとする課題】しかしながら、ウルツ鉱型結晶に特有の価電子帯の非縮帯バンド（ｂａｎｄ）構造に因り（生駒　俊明、生駒　英明共著、「化合物半導体の基礎物性入門」（１９９１年9月１０日、（株）培風館発行初版）、１７頁参照）、ｐ形の伝導形を呈する低抵抗の窒化アルミニウム・ガリウム・インジウム（$Al_\alpha Ga_\beta In_\gamma N$：$0 \leqq \alpha \leqq 1$、$0 \leqq \beta \leqq 1$、$0 \leqq \gamma \leqq 1$、$\alpha+\beta+\gamma=1$）は、容易には形成できない。従来技術の通例に依れば、低い抵抗のｐ形ＩＩＩ族窒化物半導体層を得るには、第ＩＩ族元素等のｐ形不純物を故意に添加（ｄｏｐｉｎｇ）してＩＩＩ族窒化物半導体層を形成した後、同層内より水素原子（プロトン）を脱離させるための熱処理を施す必要があるとされる（特開平５－１８３１８９号公報参照）。

【０００６】また、縦しんば煩雑な熱処理工程等を経由して得た低抵抗の$Al_\alpha Ga_\beta In_\gamma N$（$0 \leqq \alpha \leqq 1$、$0 \leqq \beta \leqq 1$、$0 \leqq \gamma \leqq 1$、$\alpha+\beta+\gamma=1$）層を障壁層として利用しようとしても、今度は、発光層を構成する

$Ga_XIn_{1-X}N$（０≦Ｘ≦１）層を積層させる順序に制約を生ずる。例えば、禁止帯幅を互いに異にする、即ち、発光波長を相違する３層の$Ga_XIn_{1-X}N$層をさせて多波長発光用途の発光層を構成するに際し、最も長波長の発光をもたらす禁止帯幅の最も小さな$Ga_XIn_{1-X}N$層を３層の中間に配置しなければならない制約がある（上記の特開２００１－１６８３８４号公報参照）。これは、$Al_\alpha Ga_\beta In_\gamma N$（$0 \leqq \alpha \leqq 1$、$0 \leqq \beta \leqq 1$、$0 \leqq \gamma \leqq 1$、$\alpha+\beta+\gamma=1$）等のＩＩＩ族窒化物半導体では、正孔（ｈｏｌｅ）の拡散長（ｄｉｆｆｕｓｉｏｎ　ｌｅｎｇｔｈ；移動度に対応する）が電子（ｅｌｅｃｔｒｏｎ）に比較して約１桁も小さいことを勘案して、発光をもたらすために注入した正孔と電子の放射再結合を各層で平均的に起こさせるためである。

【０００７】即ち、多波長の発光をもたらす複数の$Ga_XIn_{1-X}N$（０≦Ｘ≦１）層の重層構造からなる発光層を挟持する障壁層を、$Al_\alpha Ga_\beta In_\gamma N$（$0 \leqq \alpha \leqq 1$、$0 \leqq \beta \leqq 1$、$0 \leqq \gamma \leqq 1$、$\alpha+\beta+\gamma=1$）から構成する従来技術の問題点は、（１）障壁層を構成するに適する低抵抗のｐ形伝導層を簡易に得られない、及び（２）正孔と電子とに拡散長の大きな差異があるため、発光層の構成層の積層順序に制限が加わることである。本発明は上記の従来技術の問題点に鑑みなされたもので、（Ａ）ｐ形及びｎ形の双方の伝導形の低抵抗層を煩雑な後工程を要せずに簡易に構成でき、尚且つ、（Ｂ）正孔と電子の移動度に然して大きな差異がない化合物半導体材料から障壁層を構成することとし、もって、簡便に構成することができるｐｎ接合型ヘテロ接合構造の発光部を具備する化合物半導体発光素子を提供するものである。

【０００８】

【課題を解決するための手段】即ち、本発明は、

（１）結晶からなる基板と、基板上に設けられたアンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層と、第１の障壁層上に設けられた、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる、第１または第２の伝導形の発光層とを備えたｐｎ接合型化合物半導体発光素子に於いて、第１の障壁層に最も近い側に設ける発光層の構成層（第１の発光層構成層）が、リン（Ｐ）を含むＩＩＩ族窒化物半導体から構成されていることを特徴とするｐｎ接合型化合物半導体発光素子。

（２）基板が、珪素（Ｓｉ）単結晶基板であることを特徴とする上記（１）に記載のｐｎ接合型化合物半導体発光素子。

（３）発光層の構成層が、窒化リン化ガリウム・インジウム（$Ga_XIn_{1-X}P_{1-Y}N_Y$：$0 \leqq X \leqq 1$、$0 < Y < 1$）または窒化リン化ガリウム（$GaP_{1-Y}N_Y$：$0 < Y < 1$）からなることを特徴とする上記（１）または（２）に記載のｐｎ接合型化合物半導体発光素子。

（４）第１の障壁層が、発光層を構成する複数の発光層構成層の何れよりも、少なくとも０．１ｅＶ以上禁止帯幅を大とすることを特徴とする上記（１）乃至（３）の何れか１項に記載のｐｎ接合型化合物半導体発光素子。
（５）第１の障壁層の表面上にＩＩＩ族窒化物半導体からなる中間層が形成され、該中間層に接合させて第１の発光層構成層が設けられていることを特徴とする上記（１）乃至（４）の何れか１項に記載のｐｎ接合型化合物半導体発光素子。
（６）中間層が、第１の発光層構成層を構成するＩＩＩ族窒化物半導体以上の禁止帯幅を有するＩＩＩ族窒化物半導体から構成されていることを特徴とする上記（５）に記載のｐｎ接合型化合物半導体発光素子。
（７）中間層が、第１の発光層構成層をなすＩＩＩ族窒化物半導体を構成する元素を含むＩＩＩ族窒化物半導体から構成されていることを特徴とする上記（５）または（６）に記載のｐｎ接合型化合物半導体発光素子。
（８）発光層の最表層をなす発光層構成層の表面に、アンドープで第２の伝導形のリン化硼素系半導体からなる第２の障壁層が設けられていることを特徴とする上記（１）乃至（７）の何れか１項に記載のｐｎ接合型化合物半導体発光素子。
（９）発光層の最表層をなす発光層構成層が、リン（Ｐ）を含む第１または第２の伝導形のＩＩＩ族窒化物半導体から構成されていることを特徴とする上記（８）に記載のｐｎ接合型化合物半導体発光素子。
（１０）結晶からなる基板上に、アンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層を形成し、さらに該第１の障壁層上に、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる、第１または第２の伝導形の発光層を形成するｐｎ接合型化合物半導体発光素子の製造方法に於いて、第１の障壁層に最も近い側に設ける発光層の構成層（第１の発光層構成層）を、リン（Ｐ）を含むＩＩＩ族窒化物半導体から構成することを特徴とするｐｎ接合型化合物半導体発光素子の製造方法。
（１１）第１の障壁層の表面上にＩＩＩ族窒化物半導体からなる中間層を形成し、該中間層に接合させて第１の発光層構成層を形成することを特徴とする上記（１０）に記載のｐｎ接合型化合物半導体発光素子の製造方法。
（１２）発光層の最表層をなす発光層構成層の表面に、アンドープで第２の伝導形のリン化硼素系半導体からなる第２の障壁層を形成することを特徴とする上記（１０）または（１１）に記載のｐｎ接合型化合物半導体発光素子の製造方法。
（１３）上記（１）乃至（９）の何れか１項に記載のｐｎ接合型化合物半導体発光素子からなる白色発光ダイオード、である。
【０００９】
【発明の実施の形態】本発明の第１の実施形態に於いて、基板には、種々の結晶を基板として利用できる。例えば、ｎ形またはｐ形の導電性の珪素（Ｓｉ）や炭化珪素（ＳｉＣ）等の第ＩＶ族の半導体単結晶、リン化ガリウム（ＧａＰ）のＩＩＩ－Ｖ族化合物半導体単結晶を基板として利用できる。基板の表面の結晶面は不問であるが、通常は｛１．０．０．｝、｛１．１．０．｝或いは｛１．１．１．｝結晶面、六方晶結晶にあっては｛０．０．０．１．｝或いは｛１．１．－２．１．｝結晶面とするのが通例である。上記の低次のミラー（Ｍｉｌｌｅｒ）指数の結晶面より、角度にして数度、傾斜した結晶面を表面とする単結晶も基板として利用できる。絶縁性のα－アルミナ（$\alpha-Al_2O_3$）単結晶やペロブスカイト結晶型酸化物単結晶を基板として利用できないことはないが、導電性の単結晶を基板とすれば、基板の裏面に正負、何れかの極性のオーミック（Ｏｈｍｉｃ）性電極を裏面電極として敷設でき、簡便にＬＥＤ等の発光素子を構成するに寄与できる。導電性の単結晶を基板とするにあって、単結晶の伝導形はｎ形またはｐ形の何れでも構わない。抵抗率を１ミリオーム（mΩ）・cm以下とする低い比抵抗（抵抗率）の導電性単結晶基板は、順方向電圧（所謂、V_f）の低いＬＥＤをもたらすに貢献する。また、放熱性に優れるため安定した発振をもたらすＬＤを構成するに有効となる。
【００１０】上記の結晶基板上に設ける第１の障壁層は、本発明では、硼素（Ｂ）とリン（Ｐ）とを構成元素として含むリン化硼素系化合物半導体層から構成する。例えば、$B_\alpha Al_\beta Ga_\gamma In_{1-\alpha-\beta-\gamma} P_{1-\delta} As_\delta$（$0<\alpha\leq1$、$0\leq\beta<1$、$0\leq\gamma<1$、$0<\alpha+\beta+\gamma\leq1$、$0\leq\delta<1$）から構成する。また、例えば、$B_\alpha Al_\beta Ga_\gamma In_{1-\alpha-\beta-\gamma} P_{1-\delta} N_\delta$（$0<\alpha\leq1$、$0\leq\beta<1$、$0\leq\gamma<1$、$0<\alpha+\beta+\gamma\leq1$、$0\leq\delta<1$）から構成できる。第１の障壁層は、後述の第２の障壁層よりも位置的に結晶基板の表面により近接して設けられる障壁層である。第１の障壁層をなすリン化硼素系半導体層の伝導形を、本発明では、第１の伝導形と仮称する。導電性の結晶を基板として発光素子を構成するにあって、基板をなす結晶の伝導形は第１の伝導形とするのが好適である。例えば、ｐ形の｛１．１．１．｝結晶面を有するＳｉ単結晶基板（｛111｝－Ｓｉ単結晶基板）上には、ｐ形のリン化硼素系半導体層からなる第１の障壁層を設ける。また、第１の障壁層を構成する第１の伝導形のリン化硼素系半導体層と結晶基板との間に非晶質或いは多結晶からなる緩衝層を設け、基板上に該緩衝層を介して第１の障壁層を設けることとすれば、ミスフィット（ｍｉｓｆｉｔ）転位等の少ない結晶性に優れる第１の障壁層を得ることができる。上記の緩衝層に依って、基板の単結晶材料と第１の伝導形のリン化硼素系半導体層との格子ミスマッチ（ｍｉｓｍａｔｃｈ）を緩和する作用が発揮されるからである。
【００１１】第１の障壁層は、伝導形を制御するための

不純物を故意に添加（ｄｏｐｉｎｇ）しない、所謂、アンドープ（ｕｎｄｏｐｅ）のリン化硼素系半導体層から特に、好適に構成できる。リン化硼素系半導体として代表的な単量体のリン化硼素（ｂｏｒｏｎ－ｍｏｎｏｐｈｏｓｐｈｉｄｅ：ＢＰ）を例にして説明すれば、ＢＰには、成長条件に依存するもののアンドープ状態で既に、硼素（Ｂ）空孔（ｖａｃａｎｃｙ）を占めるリン（Ｐ）原子、或いはリン（Ｐ）空孔を占有する硼素（Ｂ）原子が多量に存在している。硼素空孔を占めるリンはドナー（ｄｏｎｏｒ）として働き、リン空孔を占有する硼素はアクセプタ（ａｃｃｅｐｔｏｒ）として作用する。しかも、これらの空孔の関与するドナー或いはアクセプタ成分は、アンドープで低抵抗のｐ形またはｎ形の導電層をもたらすに充分な濃度をもってＢＰ層の内部に約10^{19} cm^{-3}を越えて多量に存在し得る。従って、障壁層を敢えて、伝導形を制御するためのｎ形またはｐ形不純物をドーピングしたリン化硼素系半導体層から構成する必要は無くなる。即ち、第１の障壁層をアンドープのリン化硼素系半導体層から構成すれば、伝導形に依存して異種の不純物をドーピングする煩雑な操作を要せず、また、低抵抗のｐ形層を得るための熱処理等の煩雑な従来技術を実施する必要もなく、簡易に低抵抗の導電性を有する第１の障壁層を得られる利点がある。

【００１２】第１の障壁層は、発光層を構成する複数の発光層構成層の何れよりも禁止帯幅を大とするのが望ましく、少なくとも０．１ｅＶ以上、望ましくは０．２ｅＶ以上禁止帯幅を大とするリン化硼素系半導体層から構成するのが望ましい。発光層構成層の最大の禁止帯に比較し、約０．３ｅＶ～０．４ｅＶ大きな禁止帯幅のリン化硼素系半導体層からは更に好適に第１の障壁層を構成できる。特に、禁止帯幅を約２．８ｅＶ以上で約６ｅＶ未満とするリン化硼素系半導体層は、第１の障壁層として好適に利用できる。例えば、室温での禁止帯幅を３．０±０．２ｅＶとする単量体のリン化硼素（ＢＰ）層は、有機金属化学的気相堆積（ＭＯＣＶＤ）法では、７５０℃以上１２００℃以下の温度に於いて、ＭＯＣＶＤ成長反応系へ供給する構成元素源の濃度比率（所謂、Ｖ／ＩＩＩ比率）及び成長速度を好適とすることにより形成できる。例えば、成長速度を毎分２ｎｍ～毎分３０ｎｍ以下に設定することにより形成できる。第１の障壁層をなす第１の伝導形のリン化硼素系半導体層の層厚は約５０ｎｍを越え約３０００ｎｍ以下であるのが好適である。キャリア濃度は、約7×10^{17} cm^{-3}以上で約1×10^{20} cm^{-3}以下であるのが適する。リン化硼素系半導体には、アンドープであっても、10^{19} cm^{-3}～10^{20} cm^{-3}程度の高濃度でキャリアが存在しているため、障壁層を構成するに適する数mΩ・ｃｍ程度の低抵抗の導電層は簡易に得られる。

【００１３】第１の伝導形の第１の障壁層上には、禁止帯幅を相違する複数の構成層を重層させた発光層を積層

する。発光層をなす各構成層は例えば、窒化ガリウム・インジウム（$Ga_XIn_{1-X}N$：$0\leqq X\leqq1$）または窒化リン化ガリウム（$GaP_{1-Y}N_Y$：$0<Y<1$）等のＩＩＩ族窒化物半導体層から構成できる。$GaP_{1-Y}N_Y$（$0<Y<1$）の禁止帯幅は、窒素組成（＝Ｙ）或いはリン組成（＝１－Ｙ）の僅かな変化に対応して、$Ga_XIn_{1-X}N$（$0\leqq X\leqq1$）と同様に非線形的に急激に変化させられる（Ａｐｐｌ．Ｐｈｙｓ．Ｌｅｔｔ．，６０（１９９２）、２５４０～２５４２頁参照）。このため、$GaP_{1-Y}N_Y$（$0<Y<1$）は、比較的長波長の発光をもたらすための発光層の構成層として好適に利用できる。発光層は異なるＩＩＩ族窒化物半導体材料からなる構成層を重層させて構成することもできる。例えば、窒化ガリウム（ＧａＮ）、窒化ガリウム・インジウム混晶（$Ga_XIn_{1-X}N$：この場合、$0\leqq X<1$）及び窒化リン化ガリウム（$GaP_{1-Y}N_Y$：$0<Y<1$）という互いに異なるＩＩＩ族窒化物半導体材料からなる３層の構成層を重層させて発光層を構成できる。発光層を構成するための構成層の数量には、取り立てて限定はないが、所望の色調の発光は一般には３色の混色に依り帰結されることから、通常は構成層は多くとも３層程度とするのが望ましい。各構成層の伝導形は第１または第２の伝導形に統一する必要がある。第１の伝導形の第１の障壁層に、第２の伝導形の構成層からなる第２の伝導形の発光層を接合させれば、ｐｎ接合型単一ヘテロ（Ｓｉｎｇｌｅ Ｈｅｔｅｒｏ：ＳＨ）の発光部を構成できる。

【００１４】発光層を構成する各構成層のキャリア濃度は相違しても差し支えは無い。また、発光層を構成する各構成層の層厚は相違しても差し支えは無いが、通常は、視感度の低い波長の発光をもたらす発光層構成層の層厚は、他層に比較して大とすると、混色させた際に好適な演色性が得られる。例えば、補色の関係にある青色と黄色の発光を混色させて白色光を得ようとするにあって、黄色光よりも視感度の低い青色光を発する発光層構成層の層厚を、黄色光を発する発光層構成層のそれよりも厚くする例を挙げられる。発光を単結晶基板とは反対側の外部方向へ取り出す方式のＬＥＤでは、最も長波長の発光をもたらす発光層構成層を単結晶基板側に最も近接して配置するのが望ましい。例えば、上記の青色光と黄色光の各々を発光する構成層から白色光を発する発光層を得るにあって、黄色光を発する構成層を基板側の第１の障壁層側に配置する手段を例示できる。逆に、例えば、単結晶基板を除去して、元来、在った単結晶基板側から発光を取り出すＬＥＤにあっては、最も長波長の発光をもたらす発光層構成層を、単結晶基板より最も遠隔となる位置に配置するのが望ましい。

【００１５】発光層を構成する構成層にあって、第１の伝導形のリン化硼素系半導体層からなる第１の障壁層に最も近い側に設ける構成層を本発明では、第１の発光層構成層と仮称する。この第１の発光層構成層を、特にリ

ン（Ｐ）を含むＩＩＩ族窒化物半導体からなる結晶層から構成する。第１の発光層構成層として適するリン（Ｐ）を含むＩＩＩ族窒化物半導体には、窒化リン化ガリウム・インジウム（$Ga_{X}In_{1-X}P_{1-Y}N_{Y}$：０≦Ｘ≦１、０＜Ｙ＜１）や窒化リン化ガリウム（$GaP_{1-Y}N_{Y}$：０＜Ｙ＜１）等を例示できる。これらのリン（Ｐ）を含むＩＩＩ族窒化物半導体層では、リン（Ｐ）の組成を僅かに数％変化させることで、禁止帯幅を変化させられ、発光波長を変化させることができる。即ち、多波長の発光を与える複数の発光層構成層を、リン組成に僅かな変化を与えるのみで構成できる利点がある。ＩＩＩ族構成元素のガリウム（Ｇａ）、インジウム（Ｉｎ）の組成比が同一の場合、一般に、リン（Ｐ）の組成比の増大と共に、禁止帯幅は減少する。従って、長波長の発光層構成層を得るに好都合となる。

【００１６】リン化硼素系半導体層から構成した第１の障壁層（クラッド層）上に積層したリン（Ｐ）を含む第１の発光層構成層は、表面の平坦性と連続性に富に優れたものとなるため、例えば、量子井戸（Ｑｕａｎｔｕｍ Ｗｅｌｌ：ＱＷ）構造をなす井戸（ｗｅｌｌ）層として有効に利用できる。特に、直接遷移型の半導体材料からなる第１の発光層構成層は、高い発光強度をもたらす井戸層として優位に利用できる。第１のリン化硼素系半導体層からなる障壁層に第１の発光層構成層を井戸層として積層すれば、一端を井戸層とする単一（ｓｉｎｇｌｅ）または多重（ｍｕｌｔｉ）量子井戸構造の発光層を構成できる。本発明にあって、多重量子井戸構造（ＭＱＷ）を構成する各井戸層は、禁止帯幅を相違するＩＩＩ族窒化物半導体材料から構成する。互いに異なるＩＩＩ族窒化物半導体材料から各井戸層を構成しても構わないが、各井戸層の伝導形は第１の発光層構成層の伝導形に一致させる。ＱＷ構造の他の一端、即ち、終端は井戸層または井戸層に対する障壁層（バリア層）の何れからも構成できる。発光層構成層と障壁（ｂａｒｒｉｅｒ）層とを交互に周期的に重層させるＭＱＷ構造にあって、障壁層は、発光層構成層と同一の伝導形を有し、且つ発光層構成層よりも大きな禁止帯幅の半導体層から構成するが好ましいのは勿論である。

【００１７】第１の発光層構成層をなすリン（Ｐ）を含むＩＩＩ族窒化物半導体層にあって、層内のリン（Ｐ）濃度が拡散等の要因に因り増減すると、それに付随して禁止帯幅も変化してしまう。本発明の第２の実施形態では、第１の発光層構成層を、第１の障壁層をなすアンドープのリン化硼素系半導体層の表面上に形成された、ＩＩＩ族窒化物半導体からなる中間層に接合させて設ける。中間層は、第１の障壁層をなすリン化硼素系半導体層から発光層へ熱拡散して来るリン（Ｐ）または硼素（Ｂ）を捕獲して、発光層内へ侵入するリン（Ｐ）または硼素（Ｂ）の量が徒に増加するのを防ぐ役目を果たす。また、例えば、珪素単結晶（シリコン）を基板として利用した際に、同基板から遊離した珪素（Ｓｉ）が発光層内への侵入してキャリア濃度に変化を来すのを妨害する作用を有する。即ち、中間層は、例えば、所望の波長の発光が得られる様な禁止帯を有し、また、高強度の発光をもたらすに好適なキャリア濃度を有する発光層について、外来性の原子に因り禁止帯幅並びにキャリア濃度が変動するのを抑止する作用を有する。本発明では、発光層の下地の第１の障壁層を、アンドープのリン化硼素系半導体層より構成することとしているので、中間層は、第１の障壁層のドーパント（ｄｏｐａｎｔ）より、第１の障壁層を構成するリン（Ｐ）または硼素（Ｂ）、特に、リン（Ｐ）の発光層内への徒な拡散を抑制する目的に活用する。

【００１８】リン（Ｐ）の熱拡散は、第１の障壁層をなすアンドープのリン化硼素系半導体層上に高温の成長環境下で発光層を積層する際に顕著に起こる。例えば、窒化ガリウムインジウム発光層の長温度が概ね、６５０℃～９５０℃であるのに鑑みると、発光層へ侵入するリンの濃度を徒に増量させないためには、中間層の層厚は大凡、約２０ｎｍ～約５００ｎｍとするのが望ましい。また、中間層自体から発光層或いは第１の障壁層の内部への不純物の拡散を防止するため、中間層はアンドープで高純度であり、且つリンを含まない導電性の半導体層、特にＩＩＩ族窒化物半導体層から構成するのが最適である。発光層をＩＩＩ族窒化物半導体から構成する関係上、中間層を同じくＩＩＩ族窒化物半導体から構成すれば、間隙の無い連続な発光層を簡便に得られる。また、リン化硼素系半導体層の成長温度より低温で成膜できる導電性のＩＩＩ族窒化物半導体層より中間層を構成することとすると、第１の障壁層から発光層へ拡散するリンの濃度を減少させるに効果を上げられる。具体的な中間層を構成するための材料として、窒化アルミニウム・ガリウム（$Al_{X}Ga_{1-X}N$：０≦Ｘ≦１）を例示できる。

【００１９】本発明の第３の実施形態では、中間層を、第１の発光層構成層を構成するＩＩＩ族窒化物半導体以上の禁止帯幅を有するＩＩＩ族窒化物半導体から構成する。例えば、$GaP_{1-Y}N_{Y}$（０＜Ｙ＜１）からなる第１の発光層構成層について、中間層を$Al_{X}Ga_{1-X}N$（０＜Ｘ≦１）から構成する例がある。第１の発光層構成層を越える禁止帯幅の中間層は、第１の発光層構成層に対する障壁（ｂａｒｒｉｅｒ）層として作用できる。即ち、この様な中間層と第１の発光層構成層との積層構成を基にすれば、障壁層を一端とする量子井戸構造の発光層を構成できる。中間層の伝導形は、第１または第２の伝導形の何れでも構わないが、第１の発光層構成層と同一とするのが望ましい。中間層の禁止帯幅は、第１の発光層構成層よりも大きく、且つ第１の障壁層のそれ以下とすると、例えば、ＬＥＤにあって順方向電圧（所謂、V_{f}）を低減するに効果がある。好適な構成例として、室温での禁止帯を３．０ｅＶとする単量体のリン化硼素

（ＢＰ）からなる第１の障壁層上に、室温禁止帯幅を２．８ｅＶとする$Ga_X In_{1-X} N$からなる中間層を介して、室温禁止帯幅を２．６ｅＶとする第１の発光層構成層を積層する例を挙げられる。

【００２０】第１の発光層構成層の下地となる中間層を、第１の発光層構成層をなすＩＩＩ族窒化物半導体層を構成する元素（構成元素）を含むＩＩＩ族窒化物半導体から構成することとすると、間隙の無い連続性のある第１の発光層構成層を得るに有効となる。中間層に含ませた第１の発光層構成層の構成元素の「成長核」としての働きに依り、第１の発光層構成層の成膜を円滑に進行させることができる。本発明の第４の実施形態の好例として、例えば、窒化ガリウム（ＧａＮ）からなる中間層上に、窒化リン化ガリウム・インジウム（$Ga_X In_{1-X} P_{1-Y} N_Y$：$0 \leq X \leq 1$、$0 < Y < 1$）からなる発光層構成層を設ける例がある。発光層構成層、特に、短波長光を出射する発光層は禁止帯幅の大きなＩＩＩ族窒化物半導体等から構成するのがもっぱらである。ＩＩＩ族窒化物半導体層の成膜温度は例えば、約７００℃～約１２００℃と高温である。このため、中間層は、高温でのＩＩＩ族窒化物半導体層の成膜時に変質しない、高融点のＩＩＩ族窒化物半導体材料から構成するのが好適である。

【００２１】発光層の最表層をなす発光層構成層の表面に、第２の伝導形のアンドープのリン化硼素系半導体からなる第２の障壁層を設ける構成とすれば、第１の障壁層共々、発光層を挟持してｐｎ接合型ＤＨ構造の発光部を構成できる。本発明の第５の実施形態では、第１の障壁層と同様に、第２の障壁層も例えば、$B_\alpha Al_\beta Ga_\gamma In_{1-\alpha-\beta-\gamma} P_{1-\delta} As_\delta$（$0 < \alpha \leq 1$、$0 \leq \beta < 1$、$0 \leq \gamma < 1$、$0 < \alpha+\beta+\gamma \leq 1$、$0 \leq \delta < 1$）や$B_\alpha Al_\beta Ga_\gamma In_{1-\alpha-\beta-\gamma} P_{1-\delta} N_\delta$（$0 < \alpha \leq 1$、$0 \leq \beta < 1$、$0 \leq \gamma < 1$、$0 < \alpha+\beta+\gamma \leq 1$、$0 \leq \delta < 1$）等のリン化硼素系半導体から構成する。第２の障壁層は、第１の障壁層とは伝導形を反対とするアンドープのリン化硼素系半導体層から構成する。例えば、ｐ形の第１の障壁層に対し、第２の障壁層はアンドープのｎ形リン化硼素系半導体から構成する。リン化硼素系半導体では、伝導形を制御する不純物を故意に添加（＝ドーピング）せずとも第１或いは第２の伝導形の導電性を有する半導体層がもたらされる利点がある。従って、第２の障壁層をアンドープのリン化硼素系半導体層から形成することとすれば、伝導形に依って添加する不純物種を変換する必要がある煩雑なドーピング操作を回避でき、尚且つ簡便に低抵抗で導電性を有する第２の障壁層を構成できる。

【００２２】ＩＩＩ族窒化物半導体層から構成する発光層の最表層上に、第２の障壁層をなすアンドープのリン化硼素系半導体層を設けるにあたり、第２の障壁層を、リン（Ｐ）を含む第１または第２の伝導形のＩＩＩ族窒化物半導体からなる発光層の最表層上に設けることとすると、間隙の無い連続性に優れる第２の障壁層が得られる。発光層の最表層とは、発光層を構成する発光層構成層にあって、発光層の表面をなす構成層を云う。本発明の第６の実施形態の好例として、直接遷移型のｎ形$GaN_{1-Y} P_Y$からなる発光層の最表層に接合させて、アンドープのｎ形リン化硼素（ＢＰ）層からなる第２の障壁層を設ける構成を挙げられる。リン化硼素（ＢＰ）は、従来のＩＩＩ族窒化物半導体とは異なり、電子と正孔の移動度は桁違いには相違しない。即ち、双方のキャリアの拡散長には、ＩＩＩ族窒化物半導体程の差異は無い。従って、発光層構成層の積層順序には従来の如くの厳密な制限は加わらない。しかし、例えば、第２の障壁層を通過させて発光を外部へ取り出す方式のＬＥＤにあって、発光層の最表層は、他の発光層構成層に比較して、最も短い波長の発光をもたらす発光層構成層から構成するのが望ましい。即ち、この方式のＬＥＤにあって、発光層の最表層をなすＩＩＩ族窒化物半導体層のリン（Ｐ）含有量或いはリン組成は最短の発光波長を与える含有量或いは組成とする必要がある。例えば、リン組成比（Ｙ）をそれぞれY_1、Y_2、Y_3（但し、$0 \leq Y_1 < Y_2 < Y_3 \leq 0.15$）とする３層の$GaN_{1-Y} P_Y$（$Y = Y_1$、$Y_2$、$Y_3$）層を重層させて発光層を構成するにあって、発光層の最表層は、最も禁止帯幅の大きく、従って、最も短波長の発光をもたらす$GaN_{1-Y_1} P_{Y_1}$層から構成する。

【００２３】

【作用】第１の障壁層をなすアンドープのリン化硼素系半導体層に最近接して設ける第１の発光層構成層に含まれるリン（Ｐ）は、第１の発光層構成層をなすＩＩＩ族窒化物半導体層の禁止帯幅を減少させる作用を有し、これより、長波長の発光をもたらす第１の発光層構成層を構成するに貢献できる。

【００２４】第１の障壁層をなすアンドープのリン化硼素系半導体層と第１の発光層構成層との中間に設けるＩＩＩ族窒化物半導体からなる中間層は、第１の障壁層をなすリン化硼素系半導体層から第１の発光層構成層に拡散して来るリン（Ｐ）を捕捉して、発光層の内部のリン（Ｐ）濃度及び組成を維持する作用をする。

【００２５】複数の構成層を重層させてなる発光層の最表層を構成する、リン（Ｐ）を含む第１または第２の伝導形のＩＩＩ族窒化物半導体からなる発光層構成層は、間隙の無い連続性に優れる第２の伝導形のアンドープのリン化硼素系半導体からなる第２の障壁層をもたらす作用を有する。

【００２６】

【実施例】（第１実施例）青色光と黄色光を各々発光する２層の発光層構成層からなる発光層を備えたｐｎ接合型ヘテロ構造のＬＥＤを作成する場合を例にして、本発明の内容を具体的に説明する。

【００２７】本第１実施例に係わるＬＥＤ１Ｂの平面模式図を図１に示す。また、図１に示す破線Ｘ－Ｘ’に沿

ったＬＥＤ１Ｂの断面模式図を図２に示す。

【００２８】ＬＥＤ１Ｂ用途の積層構造体１Ａは、硼素（Ｂ）が添加されたｐ形（１１１）－Ｓｉ単結晶を基板１０１として形成した。基板１０１上には、トリエチル硼素（$(C_2H_5)_3B$）／ホスフィン（PH_3）／水素（H_2）系常圧ＭＯＣＶＤ法により、４５０℃で、ａｓ－ｇｒｏｗｎ状態で非晶質を主体とするリン（Ｐ）と硼素（Ｂ）とを含む緩衝層１０２を堆積した。緩衝層１０２の層厚は５ｎｍとした。

【００２９】緩衝層１０２の成膜を終了した後、基板１０１の温度を１０５０℃に上昇させた。昇温後、上記のＭＯＣＶＤ気相成長手段を利用して、緩衝層１０２の表面上に、アンドープでｐ形のリン化硼素（ＢＰ）層からなる第１の障壁層１０３を積層させた。第１の障壁層１０３をなすｐ形リン化硼素層の層厚は約４５０ｎｍとし、キャリア濃度は約2×10^{19} cm^{-3}であった。第１の障壁層１０３は、室温での禁止帯幅を約３ｅＶとするｐ形リン化硼素から構成した。

【００３０】第１の障壁層１０３の気相成長を終了した後、PH_3とH_2とをＭＯＣＶＤ成長反応系に流通しつつ、珪素単結晶基板１０１の温度を８００℃に低下させた。その後、第１の障壁層１０３上に接合させて、$(CH_3)_3Ga$／トリメチルインジウム（$(CH_3)_3In$）／アンモニア（NH_3）／PH_3／水素（H_2）系常圧ＭＯＣＶＤ法により、第１の発光層構成層１０５－１をなすｎ形窒化リン化ガリウム・インジウム（$Ga_{0.55}In_{0.45}N_{0.95}P_{0.05}$）層を設けた。第１の発光層構成層１０５－１のリン組成は、黄色帯の発光が得られる比率（＝０．０５）とし、層厚は約６８ｎｍとした。第１の発光層構成層１０５－１上には、上記の常圧ＭＯＣＶＤ法により８００℃で成長させたｎ形窒化ガリウム・インジウム（$Ga_{0.90}In_{0.10}N$）層からなる第２の発光層構成層１０５－２を設けた。第２の発光層構成層１０５－２の層厚は約１１０ｎｍとした。第１及び第２の発光層構成層１０５－１、１０５－２から発光層１０５を構成した。

【００３１】積層構造体１Ａの形成を終了した後、一般的な２次イオン質量分析法（ＳＩＭＳ）に依り、発光層１０５の内部のリン（Ｐ）原子濃度を定量した。第１の発光層構成層１０５－１の内部の平均的なリン原子濃度は約8×10^{20}原子／cm^3、また、第２の発光層構成層１０５－２の内部の平均的なリン原子濃度は約4×10^{17}原子／cm^3と各々、定量された。これより、第１及び第２の発光層構成層１０５－１、１０５－２では、第１の障壁層１０３からのリン（Ｐ）原子の侵入に因るリン原子濃度の若干の増量が検知された。

【００３２】発光層１０５の表面の中央部に、発光層１０５表面に接触する側に金（Ａｕ）からなる薄膜層を配置したＡｕ／ニッケル（Ｎｉ）／Ａｕの３層重層構造からなる表面電極１０７を設けた。結線用の台座（ｐａｄ）電極を兼ねる表面電極１０７は、直径を約１２０μｍとする円形の電極とした。また、ｐ形Ｓｉ単結晶基板１０１の裏面の略全面には、裏面電極１０８としてアルミニウム・アンチモン（Ａｌ・Ｓｂ）合金の蒸着膜からなるオーミック電極を配置してＬＥＤ１Ｂを構成した。Ａｌ・Ｓｂ蒸着膜の膜厚は約２μｍとした。表面電極１０７及び裏面電極１０８を形成した後、基板１０１をなすＳｉ単結晶基板を［２１１］方向に平行及び垂直な方向に裁断して、一辺を約３５０μｍとする正方形の、珪素単結晶１０１とは反対側の表面から外部へ発光を取り出す方式のｐｎ接合型ヘテロ構造のＬＥＤ１Ｂを構成した。

【００３３】表面電極１０７と裏面電極１０８との間に順方向に２０ミリアンペア（ｍＡ）の動作電流を通流した際に、ＬＥＤ１Ｂからは黄白色光が発せられた。黄白色光のスペクトル成分は、図３に示す如く、第１の発光層構成層１０５－１からの発光に対応する中心波長を５７０．５ｎｍとする黄色光と、第２の発光層構成層１０５－２からの発光に対応する中心波長を４８１．５ｎｍとする青色光とであった。一般的な積分球を利用して測定される相違する２波長の発光をもたらすＬＥＤ１Ｂのチップ（ｃｈｉｐ）状態での輝度は５ミリカンデラ（ｍｃｄ）となり、高発光強度の白色発光ダイオードが提供された。また、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約２．９Ｖであり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は５Ｖ以上となった。

【００３４】（第２実施例）本第２実施例では、上記の第１実施例に記載のアンドープでｐ形のリン化硼素（ＢＰ）からなる第１の障壁層１０３に接合させて中間層１０４を設けた積層構造体２ＡからＬＥＤ２Ｂを構成する場合を例にして本発明の内容を説明する。

【００３５】図４に本第２実施例に係わるＬＥＤ２Ｂの断面模式図を示す。中間層１０４以外の構成要素は、上記の第１実施例と同一としてある。従って、図４に於いて、図１及び図２に示したと同一の構成要素については、同一の符号を付して、その説明を省略する。

【００３６】中間層１０４は、アンドープでｎ形の窒化ガリウム・インジウム（$Ga_{0.95}In_{0.05}N$）層から構成した。インジウム（Ｉｎ）組成比を０．０５（＝５％）とする$Ga_{0.95}In_{0.05}N$中間層１０４は、$(CH_3)_3Ga$／$(CH_3)_3In$／NH_3／H_2系常圧ＭＯＣＶＤ法により、８００℃で気相成長させた。中間層１０４の層厚は約２５ｎｍに設定した。また、中間層１０４のキャリア濃度は約2×10^{18} cm^{-3}と見積もられた。中間層１０４は、室温での禁止帯幅を約３．２ｅＶとするウルツ鉱結晶型の$Ga_{0.95}In_{0.05}N$から構成した。

【００３７】中間層１０４上に、上記の第１実施例に記載したのと同一の構成の発光層構成層１０５－１、１０５－２からなる発光層１０５を接合させて設けて、積層構造体２Ａの形成を終了した。一般的な２次イオン質量

分析法（ＳＩＭＳ）に依れば、中間層１０４の内部のリン（Ｐ）原子濃度は約4×10^{19}原子／cm^3と定量された。また、第１の発光層構成層１０５－１内部のリン原子濃度は約8×10^{18}原子／cm^{-3}であり、第２の発光層構成層１０５－２の内部のリン原子濃度はそれ以下となった。因みに、上記の第１実施例に記載の如く、中間層１０４を設けずに、第１の障壁層１０３に直接、接合させて設けた第１の発光層構成層１０５－１では、内部のリン原子濃度が約8×10^{20}原子／cm^3の高濃度であったのを勘案すると、本発明に係わる中間層１０４は、第１の障壁層１０３から拡散して来るリン（Ｐ）原子を捕獲して、第１の発光層構成層１０５－１のリン組成比を維持するに有効となるのが示された。また、中間層１０４による第１の障壁層１０３から拡散して来る硼素（Ｂ）或いはリン（Ｐ）原子の捕獲作用に依り、中間層１０４と第１の発光層構成層１０５－１とのヘテロ接合界面の乱雑化は（光技術共同研究所編著、「光電子集積回路の基礎技術」（１９８９年8月２０日、（株）オーム社発行、第１版第１刷）、３７１～３８４頁参照）抑止される結果となった。

【００３８】第１実施例に記載したものと同じ表面電極１０７と裏面電極１０８を形成して、ＬＥＤ２Ｂを構成した。表面電極１０７と裏面電極１０８との間に順方向に２０ｍＡの動作電流を通流した際には、青白色光が発せられた。青白色光のスペクトル成分は、第１の発光層構成層１０５－１からの発光に対応する中心波長を５６６．０ｎｍとする黄緑色光と、第２の発光層構成層１０５－２からの発光に対応する中心波長を４７５．４ｎｍとする青色光とであった。一般的な積分球を利用して測定される相違する２波長の発光をもたらすＬＥＤ２Ｂのチップ状態での輝度は約５ｍｃｄとなり、高発光強度の白色発光ダイオードが提供された。また、中間層１０４と第１の発光層構成層１０５－１との接合界面の乱雑化が抑制されたため、良好な整流性が顕現され、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約３．０Ｖであり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は８Ｖ以上となった。

【００３９】（第３実施例）本第３実施例では、上記の第２実施例に記載の$Ga_{0.95}In_{0.05}N$とは異なるＩＩＩ族窒化物半導体材料から中間層１０４を構成する場合を例にして、本発明の内容を説明する。中間層１０４以外の構成要素は、上記の第１実施例及び第２実施例と同一としてある。

【００４０】図５に本第２実施例に係わるＬＥＤ３Ｂの断面模式図を示す。図５に於いて、図１乃至図３に示したと同一の構成要素については、同一の符号を付して、その説明を省略する。

【００４１】中間層１０４は、アンドープでｎ形の窒化ガリウム（ＧａＮ）層から構成した。中間層１０４は、$(CH_3)_3Ga/NH_3/H_2$系常圧ＭＯＣＶＤ法により、第１の障壁層１０３の場合と同温の１０５０℃で気相成長させた。中間層１０４の層厚は約３０ｎｍに設定した。また、中間層１０４のキャリア濃度は約2×10^{18} cm^{-3}と見積もられた。中間層１０４は、室温での禁止帯幅を約３．４ｅＶとするウルツ鉱結晶型のＧａＮから構成した。

【００４２】本第３実施例では、中間層１０４を第２実施例の場合よりも禁止帯幅を大とするＩＩＩ族窒化物半導体から構成していることに鑑み、中間層１０４をまた、発光層１０５に対する障壁（バリア）層として利用した。第１の障壁層１０３に接合させて設けた中間層１０４でもあり、下部バリア層１０４－１でもあるＧａＮ層上には、第１実施例に記載の発光波長を相違する２層の発光層構成層１０５－１、１０５－２を順次、重層させた。第２の発光層構成層１０５－２上には、$(CH_3)_3Ga/NH_3/H_2$系常圧ＭＯＣＶＤ法により、発光層構成層１０５－１，－２と同じく８００℃で気相成長させたアンドープでｎ形のＧａＮ層を上部バリア層１０４－２として接合させた。上部バリア層１０４－２のキャリア濃度は約5×10^{18} cm^{-3}とし、層厚は約３００ｎｍとした。

【００４３】一般的な２次イオン質量分析法（ＳＩＭＳ）に依れば、中間層１０４の内部の平均的なリン（Ｐ）原子濃度は、第２実施例の場合より低く、約1×10^{18}原子／cm^3と定量された。また、第１の発光層構成層１０５－１内部の平均的なリン原子濃度は約4×10^{18}原子／cm^{-3}であり、第２の発光層構成層１０５－２の内部のリン原子濃度もそれと同等となった。また、透過型電子顕微鏡（ＴＥＭ）を利用した断面ＴＥＭ観察に依れば、中間層１０４（下部バリア層１０４－１）と第１の発光層構成層１０５－１とのヘテロ接合界面での組成急峻性は良好であり、第１の障壁層１０３から拡散して来るリン（Ｐ）及び硼素（Ｂ）に因る同ヘテロ接合界面の乱雑化は抑止されるのが認められた。

【００４４】積層構造体３Ａの最表層をなす上部バリア層１０４－２の表面と珪素単結晶基板１０１の裏面の略全面に、それぞれ第１実施例に記載のものと同じ表面電極１０７および裏面電極１０８を形成して、ＬＥＤ３Ｂを構成した。表面電極１０７と裏面電極１０８との間に順方向に２０ｍＡの動作電流を通流した際には、白色光が発せられた。一般的な分光測光手段に依れば、白色光のスペクトル成分は、第１の発光層構成層１０５－１からの発光に対応する中心波長を５６５．０ｎｍとする黄緑色光と、第２の発光層構成層１０５－２からの中心波長を４７２．２ｎｍとする青色光とであった。一般的な積分球を利用して測定される相違する２波長の発光をもたらすＬＥＤ３Ｂのチップ状態での輝度は約５ｍｃｄとなり、高発光強度の白色発光ダイオードが提供された。発光強度は第２実施例に記載のＬＥＤ２Ｂとは殆ど差異は認められなかった。しかし、発光層１０５の上下にバ

リア層１０４－１、１０４－２を設ける構造とすることにより、上記の各スペクトル成分の半値幅（ＦＷＭＨ）は、第２実施例の場合に比較して、約１０ｎｍ程度小となっており、単色性に優れるＬＥＤが提供されることとなった。また、中間層１０４と第１の発光層構成層１０５－１との接合界面の乱雑化が抑制されたため、良好な整流性が顕現され、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約３．０Ｖで、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は約９Ｖとなり、併せて高耐圧のＬＥＤ３Ｂが提供された。

【００４５】（第４実施例）上記の第３実施例とは異なるＩＩＩ族窒化物半導体からなる中間層を利用してＬＥＤを構成する場合を例にして、本発明の内容を具体的に説明する。本第４実施例に係わるＬＥＤの断面構造は図５に示す通りであり、同図に掲載の中間層１０４の構成材料のみを異にするものである。

【００４６】本第４実施例では、中間層１０４を、第１実施例に記載の第１の発光層をなす$Ga_{0.55}In_{0.45}N_{0.95}P_{0.05}$層の構成元素であるガリウム（Ｇａ）及び窒素（Ｎ）を含むアンドープでｎ形の窒化アルミニウム・ガリウム混晶（$Al_{0.02}Ga_{0.98}N$）から構成した。本発明の中間層は、第１の障壁層上に、トリメチルアルミニウム（$(CH_3)_3Al$）／$(CH_3)_3Ga$／NH_3／H_2系常圧ＭＯＣＶＤ法により、第１の障壁層の場合と同温の１０５０℃で気相成長させた。中間層の層厚は約３０ｎｍに設定した。また、中間層のキャリア濃度は約3×10^{17} cm^{-3}と見積もられた。中間層は、室温での禁止帯幅を約３．４ｅＶとするウルツ鉱結晶型の$Al_{0.02}Ga_{0.98}N$から構成した。

【００４７】中間層上には、上記の第３実施例に記載のものと同じ発光層及び上部バリア層を、第３の実施例に記載の条件により設けた。本実施例４の中間層は、第１乃至第３実施例に記載の何れの中間層よりも大きな禁止帯幅を有する上に、第１の発光層構成層の構成元素を含有しているため、第１の発光層構成層は、表面を平坦とする特に連続性に優れるものとなった。また、第１の発光層構成層の表面は平滑性に優れる鏡面となったため、その層に重層させた第２の発光層構成層も表面の平坦性に優れる連続膜となった。微分干渉型光学顕微鏡及び走査電子顕微鏡（ＳＥＭ）に依る表面状態の観察では、第２の発光層構成層の表面には、層の連続性を損なう間隙或いは小孔（ピット）は殆ど視認されなかった。

【００４８】上記の第３実施例と同様にして、表面電極と裏面電極とを形成して、ＬＥＤを構成した。表面電極と裏面電極との間に順方向に２０ｍＡの動作電流を通流した際には、第３実施例の場合と同様に白色光が発せられた。各発光スペクトル成分の半値幅は、第３実施例に記載のＬＥＤと同じく、第２実施例の場合に比較して約１０ｎｍ程度小である大凡、２０ｎｍであった。一方で、本第４実施例では、中間層を第１の発光層構成層の構成元素を含むＩＩＩ族窒化物半導体から構成することにより、表面状態に優れる発光層構成層がもたらされたことを反映して、チップ状態での輝度は約７ｍｃｄとなった。この一般的な積分球を利用して測定した輝度は、第３実施例に記載のＬＥＤの約１．５倍であり、より高輝度の白色発光ダイオードが提供された。また、中間層と第１の発光層構成層との接合界面の乱雑化が抑制されたため、良好な整流性が顕現され、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約３．０Ｖとなり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は約９Ｖとなり、併せて高耐圧のＬＥＤが提供された。

【００４９】（第５実施例）本実施例５では、波長を相違する発光をもたらす複数の発光層構成層を重層させて形成した発光層上に、第２の伝導形のアンドープのリン化硼素系半導体からなる第２の障壁層を備えた、ｐｎ接合型ＤＨ構造のＬＥＤを構成する場合を例にして本発明の内容を具体的に説明する。

【００５０】本第５実施例に係わるＬＥＤ４Ｂの断面構造を図６に模式的に示す。図６に示すＬＥＤ４Ｂにあって、上記の第１実施例に記載したと同一の構成要素については、同一の符号を付してその説明を省略する。

【００５１】本第５実施例では、上記の第４実施例に記載の如くの中間層１０４上に、８００℃で発光層１０５の成長を終了した後、珪素単結晶基板１０１の温度をNH_3とH_2との混合雰囲気中で８５０℃に昇温した。昇温後、発光層１０５に、アンドープでｎ形の単量体のリン化硼素（ＢＰ）からなる第２の障壁層１０６を接合させて設けた。第２の障壁層１０６は、$(C_2H_5)_3B$／PH_3／H_2系常圧ＭＯＣＶＤ法により成長させた。第２の障壁層１０６の層厚は、第１の障壁層１０３と略同一の４５０ｎｍとした。第２の障壁層１０６は、発光層１０５からの発光を効率的に外部へ取り出すための発光透過層として作用させるため、室温での禁止帯幅を約３ｅＶとするアンドープのリン化硼素から構成した。

【００５２】積層構造体４Ａの形成を終了した後、一般的な２次イオン質量分析法（ＳＩＭＳ）に依り、中間層１０４の内部の平均的なリン（Ｐ）原子濃度は約4×10^{18}原子／cm^3と定量された。また、第１の発光層構成層１０５－１内部の平均的なリン原子濃度は約2×10^{18}原子／cm^{-3}であり、第２の発光層構成層１０５－２の内部のリン原子濃度はそれ以下となった。中間層１０４による第１の障壁層１０３から拡散して来る硼素（Ｂ）或いはリン（Ｐ）原子の捕獲作用に依り、中間層１０４と第１の発光層構成層１０５－１とのヘテロ接合界面の乱雑化は抑止されているのが、断面ＴＥＭ技法に依り認められた。

【００５３】アンドープでｎ形の第２の障壁層１０６の表面の中央部には、表面電極１０７を配置した。表面電極１０７は、第２の障壁層１０６に接触する側を金・ゲルマニウム（Ａｕ・Ｇｅ）合金膜とする、Ａｕ・Ｇｅ／

ニッケル（Ｎｉ）／Ａｕ３層重層膜から構成した。台座電極を兼ねる円形の表面電極１０７の直径は、約１１０μｍとした。ｐ形Ｓｉ単結晶基板１０１の裏面の略全面には、裏面電極１０８としてアルミニウム（Ａｌ）からなるオーミック電極を配置してＬＥＤ４Ｂを構成した。Ａｌ真空蒸着膜の膜厚は約３μｍとした。表面電極１０７及び裏面電極１０８を形成した後、Ｓｉ単結晶１０１を［２１１］方向に平行及び垂直な方向に裁断して、一辺を約３５０μｍとする正方形の、珪素単結晶１０１とは反対側の第２の障壁層１０６側から外部へ発光を取り出す方式のＬＥＤ４Ｂを構成した。

【００５４】表面電極１０７と裏面電極１０８との間に順方向に２０ｍＡの動作電流を通流した際には、主に第２の障壁層１０６を通過してＬＥＤ４Ｂからは青白色光が発せられた。青色光の発光スペクトル成分は、図３に示したと略同様であった。本第５実施例のＬＥＤ４Ｂは、ｐｎ接合型ＤＨヘテロ接合構造の発光部としたため、一般的な積分球を利用して測定される輝度は約１０ｍｃｄとなり、より高発光強度の白色発光ダイオードを提供できた。また、中間層１０４と第１の発光層構成層１０５－１との接合界面の乱雑化が抑制されたため、良好な整流性が顕現され、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約３．２Ｖであり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は５Ｖ以上となった。

【００５５】（第６実施例）発光層の最表層をなすリン（Ｐ）を含んでなる発光層構成層上に、アンドープのリン化硼素系半導体層を第２の障壁層として設けてなるｐｎ接合型ＤＨ構造のＬＥＤを構成する場合を例にして本発明の内容を具体的に説明する。

【００５６】本第６実施例に係わるＬＥＤは、断面構造が上記第５実施例と同じく図６に示す通りであり、第５実施例のＬＥＤとは発光層の最表層（第２の発光層構成層１０５－２）の構成材料のみを異にするものである。

【００５７】本第６実施例では、第２の発光層構成層１０５－２を窒化リン化ガリウム・インジウム（$Ga_{0.90}In_{0.10}N_{0.97}P_{0.03}$）層から構成した。第２の発光層構成層１０５－２は、$(CH_3)_3Ga/(CH_3)_3In/NH_3/PH_3/H_2$系常圧ＭＯＣＶＤ法により、第１の発光層構成層１０５－１と同じく８００℃で成長させた。第２の発光層構成層１０５－２の層厚は約６５ｎｍに設定した。

【００５８】第２の発光層構成層１０５－２の表面には、上記の第５実施例に記載の手法に従い、アンドープでｎ形のリン化硼素からなる第２の障壁層１０６を積層した。本第６実施例では、第２の障壁層１０６を、リン（Ｐ）を含む第２の発光層構成層１０５－２を下地として設けることとしたので、特に、表面の平滑性に優れる障壁層がもたらされた。また、ＳＥＭに依る表面観察から、第２の障壁層１０６には、間隙やピットは殆ど視認されず、連続層であるのが確認された。その後、第５実施例に記載したと同一の構成をもって、表面電極１０７及び裏面電極１０８を設けてＬＥＤを構成した。

【００５９】表面電極１０７と裏面電極１０８との間に順方向に２０ｍＡの動作電流を通流した際に、主に第２の障壁層１０６を通過してＬＥＤからは青白色光が発せられた。青色光の発光スペクトル成分は、図３に示したと略同様であった。また、一般的な積分球を利用して測定されるＬＥＤの輝度は約１０ｍｃｄとなり、高発光強度の白色発光ダイオードを提供できた。また、中間層１０４と第１の発光層構成層１０５－１との接合界面の乱雑化が抑制されているのに加えて、第２の障壁層１０６を連続性に優れるアンドープのｎ形リン化硼素層から構成したため、順方向電圧（V_f、但し順方向電流＝２０ｍＡ）は約３．０Ｖであり、逆方向電圧（V_R、但し逆方向電流＝１０μＡ）は７Ｖ以上と、第５実施例のＬＥＤより優れたｐｎ接合特性を呈するＬＥＤが提供された。

【００６０】

【発明の効果】本発明に依れば、結晶からなる基板と、基板上に設けられたアンドープで第１の伝導形のリン化硼素系半導体からなる第１の障壁層と、第１の障壁層上に設けられた、互いに禁止帯幅を相違するＩＩＩ族窒化物半導体からなる複数の構成層を重層させてなる、第１または第２の伝導形の発光層とを備えたｐｎ接合型化合物半導体発光素子に於いて、第１の障壁層に最も近い側に設ける発光層の構成層（第１の発光層構成層）をリン（Ｐ）を含む第１または第２の伝導形のＩＩＩ族窒化物半導体から構成することとしたので、黄色帯光等の比較的長波長の発光をもたらす発光層の一構成層を簡便に構成でき、従って、多波長の発光を呈するｐｎ接合型化合物半導体発光素子を簡易に提供することができる。

【００６１】また本発明に依れば、第１の発光層構成層を、アンドープのリン化硼素系半導体層からなる第１の障壁層の表面上に形成された、ＩＩＩ族窒化物半導体からなる中間層に接合させて設けることとしたので、第１の障壁層から第１の発光層構成層へ熱拡散して来るリンを捕獲する中間層の作用により、第１の発光層構成層のリン組成比を所望に維持でき、従って、発光波長の安定したｐｎ接合型化合物半導体発光素子を提供できる。

【００６２】また本発明に依れば、中間層を、特に、第１の発光層構成層を構成するＩＩＩ族窒化物半導体以上の禁止帯幅を有するＩＩＩ族窒化物半導体から構成することとしたので、中間層をバリア層とする量子井戸構造の発光層を簡便に構成でき、単色性に優れる発光成分を混色させた、多波長の発光をもたらすｐｎ接合型化合物半導体発光素子を提供できる。

【００６３】また本発明に依れば、中間層を、特に、第１の発光層構成層をなすＩＩＩ族窒化物半導体層の構成元素を含むＩＩＩ族窒化物半導体から構成することとしたので、表面の平坦性と連続性に優れる第１の発光層構

成層を得ることができ、良好なｐｎ接合特性を反映した例えば、順方向電圧或いは逆方向電圧に優れるｐｎ接合型化合物半導体発光素子を提供できる。

【００６４】また本発明に依れば、発光層の最表層をなす発光層構成層の表面に、第２の伝導形のアンドープのリン化硼素系半導体層からなる第２の障壁層を設けて、２重ヘテロ接合構造の発光部を構成することとしたので、発光強度に優れるｐｎ接合型化合物半導体多色発光素子を提供できる。

【００６５】また本発明に依れば、発光層の最表層をなす発光層構成層をリンを含む第１または第２の伝導形のＩＩＩ族窒化物半導体から構成することとしたので、連続性に優れるアンドープのリン化硼素系半導体層から第２の障壁層を形成することができ、従って、例えば、順方向電圧の低い高発光強度のｐｎ接合型２重ヘテロ構造の化合物半導体多色発光素子を提供できる。

【図面の簡単な説明】

【図１】本発明の第１実施例に係るＬＥＤの平面模式図である。

【図２】図１に示すＬＥＤの破線Ｘ－Ｘ'に沿った断面模式図である。

【図３】本発明の第１実施例に係るＬＥＤの発光スペク＊＊トルである。

【図４】本発明の第２実施例に係るＬＥＤの断面模式図である。

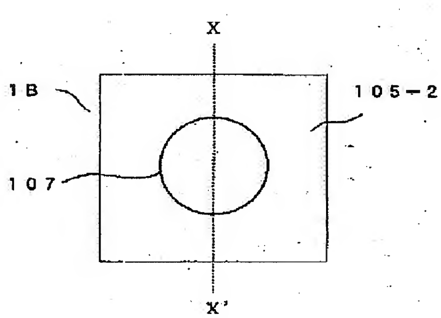
【図５】本発明の第３実施例、第４実施例に係るＬＥＤの断面模式図である。

【図６】本発明の第５実施例、第６実施例に係るＬＥＤの断面模式図である。

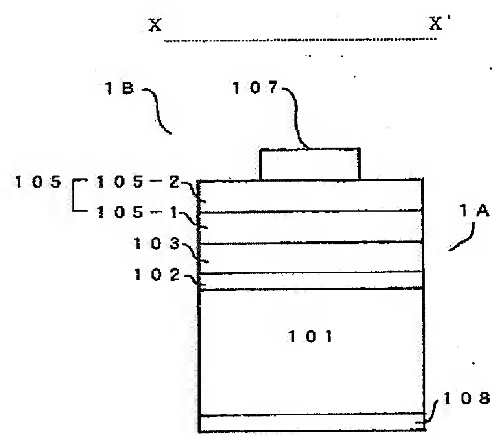
【符号の説明】

１Ａ、２Ａ、３Ａ、４Ａ　積層構造体
１Ｂ、２Ｂ、３Ｂ、４Ｂ　ＬＥＤ
１０１　基板
１０２　緩衝層
１０３　第１の障壁層
１０４　中間層
１０４－１　下部バリア層
１０４－２　上部バリア層
１０５　発光層
１０５－１　第１の発光層構成層
１０５－２　第２の発光層構成層
１０６　第２の障壁層
１０７　表面電極
１０８　裏面電極

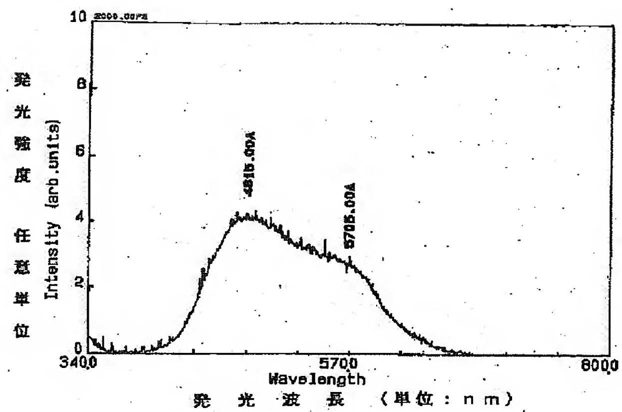
【図１】



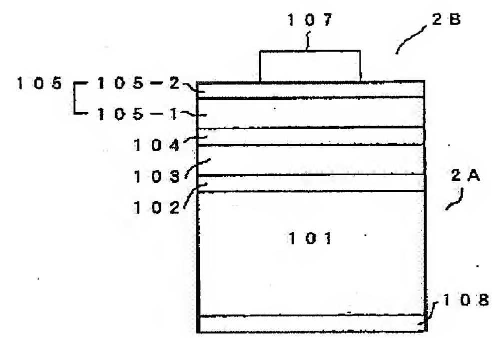
【図２】



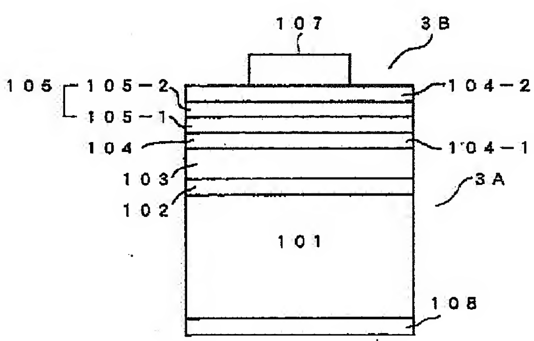
【図３】


発光強度　任意単位
Intensity (arb.units)
4815.00A
5705.00A
3400
5700
8000
Wavelength
発光波長（単位：ｎｍ）

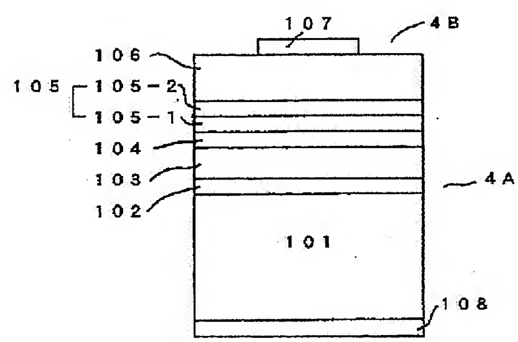
【図４】


107
2B
105
105−2
105−1
104
103
102
2A
101
108

【図５】


107
3B
105
105−2
105−1
104
103
102
104−2
104−1
3A
101
108

【図６】


107
4B
106
105
105−2
105−1
104
103
102
4A
101
108